

**Abstract.**—Feeding ecology, age and growth, length-weight relationships, and reproductive biology of two species of tonguefishes, *Cynoglossus arel* and *C. lida*, from Porto Novo, southeast coast of India, were studied during October 1981–September 1982. These tonguefishes are benthophagous; adults feed primarily on polychaetes, while juveniles more often consume smaller prey such as hyperiid amphipods and copepods. A negative correlation between spawning activity and gastrosomatic index/hepatosomatic index was noted for *C. arel*. In *C. lida*, a higher percentage of empty stomachs was observed in males than in females.

Age and growth of these tonguefishes were determined by three methods, viz, (1) Petersen method, (2) probability plot, and (3) von Bertalanffy's equation. Rate of growth from the time of hatching through the first year is higher than that of older year-classes. Both species reach commercial size during their 2d and 3d year, and have a life-span of 3–4 years. Value of  $L_{\infty}$  (theoretical maximum attainable length) is 570 mm for male and 615 mm for female *C. arel*, and 335 mm for male and 340 mm for female *C. lida*.

Analyses of the length-weight relationship showed a significant difference in length-weight slopes of male and female *C. arel*. Due to gonad development, mature female *C. lida* deviated significantly from the 'cube law.'

*Cynoglossus arel* and *C. lida* have prolonged spawning periods of 10 months, with a spawning peak in January and September, respectively. Individuals spawn only once during each season. Both sexes of both species attain first sexual maturity during the 2d year. In male *C. lida*, higher values of the gonadosomatic index (GSI) in September indicate the occurrence of fully-mature specimens during this period. A rise in Kn values (relative condition factor) corresponds with a rise in gonadal activity in female *C. arel*. The correlation coefficient shows that fecundity in *C. arel* is correlated with total length, total weight, ovary length, and ovary weight, whereas in *C. lida* it is correlated only with ovary length and ovary weight.

Manuscript accepted 4 March 1992.  
Fishery Bulletin, U.S. 90:328–367 (1992).

## Biology of two co-occurring tonguefishes, *Cynoglossus arel* and *C. lida* (Pleuronectiformes: Cynoglossidae), from Indian waters

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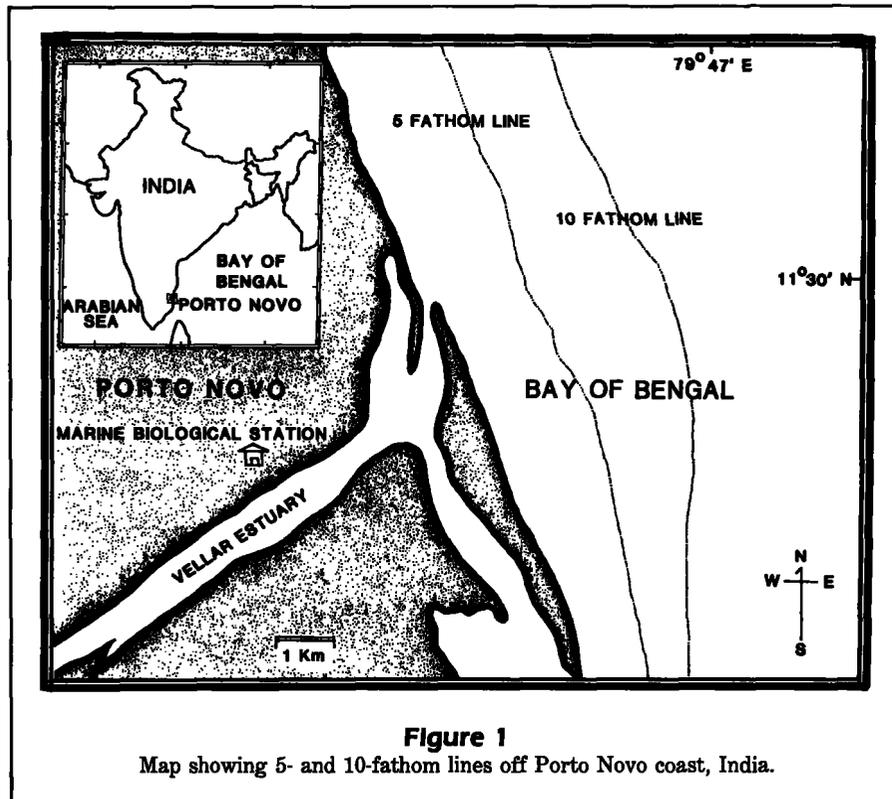
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Out of 77 species of flatfishes occurring along the east and west coasts of India (Rajaguru 1987), only one species, viz, the Malabar sole *Cynoglossus macrostomus*, constitutes an important fishery along the Malabar coast (west coast of India) (Bal and Rao 1984). The Indian halibut *Psettodes erumei*, because of its larger size and delicious flesh, fetches a high value in fish markets (Pradhan 1969); however, it does not comprise a high value fishery. Other species of flatfishes which contribute to fisheries along the Indian coasts are: *Cynoglossus macrolepidotus*, *C. arel*, *C. dubius*, *C. lida*, *C. puncticeps*, *C. bilineatus*, *C. lingua*, *Paraplagusia* spp., *Solea* spp., and *Pseudorhombus* spp. (Seshappa 1973, Ramanathan 1977, Rajaguru 1987). However, none of these species comprises a single-species fishery. Separate statistics are not reported for these species; all flatfish species are jointly reported as 'soles' (CMFRI 1969, Fischer and Bianchi 1984). Average landings of flatfishes along the Indian coast is about 2% of the total marine fish catches (Ramanathan 1977, Rajaguru 1987). Most of these flatfish species became prominent in the landings only after the introduction of trawlers (Devadoss and Pillai 1973). These species, except the malabar sole *Cynoglossus macrostomus*, are generally not the target species, but are taken incidentally in the penaeid shrimp fishery. Along the Porto Novo Coast, of the 47 flat-

fish species (Rajaguru 1987), only *Psettodes erumei*, *Pseudorhombus arsius*, *Cynoglossus arel*, and *C. lida* occur throughout the year. The latter two species are taken in a fishery throughout the year, even during the northeast monsoon period, when other marine fish are generally absent.

The biology of these two tonguefishes is poorly known, except for work on age and growth of 138 *C. lida* from the west coast of India (Seshappa 1978). The present study examines various aspects of biology, including feeding ecology, age, growth, length-weight relationships, and reproductive biology of *C. arel* and *C. lida* in Porto Novo coastal waters.

Objectives of the study on the feeding ecology of these two species of tonguefishes are to determine (a) the diet of juveniles and adults, (b) differences in diet between seasons, and (c) relationships between feeding morphology, digestive morphology, and diet. An age and growth study was also undertaken to (a) evaluate differences in growth patterns between males and females, (b) determine age of recruitment to the Porto Novo fishery, and (c) determine longevity of these two tonguefishes. The objective of the studies on length-weight relationships is to determine if there is a significant deviation from the cube law of length-weight relationship related to ontogeny and gonadal development. The final aspect



computed using data of 1281 specimens of *C. arel* (655 males, 599 females, and 27 juveniles) and 1519 specimens of *C. lida* (768 males, 723 females, and 28 juveniles). A total of 1196 specimens of *C. arel* (627 males and 569 females) and 1358 specimens of *C. lida* (718 males and 640 females) were examined for the reproductive biology studies. Some specimens were used for all four studies. Size range of the specimens was as follows: *C. arel* (males 95–360 mm TL, females 99–435 mm TL, juveniles 83–128 mm TL) and *C. lida* (males 97–248 mm TL, females 98–242 mm TL, juveniles 81–125 mm TL). Total length (TL) of each fish was measured to the nearest 1 mm; total weight (TW) was recorded to the nearest 0.1 g. Sex, maturity stages, TL, and TW were noted in fresh-caught fish. Size of monthly samples utilized for various analyses is given in Appendix.

of the study is reproductive biology. The objectives are to (1) determine the spawning season, spawning periodicity, age and size at first maturity, and (2) examine relationships between fecundity and total length, total weight, ovary length and ovary weight.

## Materials and methods

Samples of large-scaled tonguefish *Cynoglossus arel* (Bloch and Schneider 1801) and shoulder-spot tonguefish *C. lida* (Bleeker 1851) were collected twice weekly (a total of 96 collections) from commercial fish catches landed in Porto Novo, southeast coast of India (11°29'N, 79°46'E; Fig. 1), from October 1981 to September 1982. Fishing operations were confined to the upper continental shelf, to a depth of 18–22 m, up to 4 km from the coast.

A total of 1220 specimens of *C. arel* (627 males, 569 females, 24 juveniles) and 1382 specimens of *C. lida* (718 males, 640 females, 24 juveniles) were collected for stomach analyses. For the age and growth study, a total of 1203 specimens of *C. arel* (634 males and 569 females), and 1374 specimens of *C. lida* (724 males and 650 females) were utilized; since juveniles were available only for 4 months, they were not included in the age and growth study. Length-weight equations were

## Feeding ecology

Stomachs were removed and preserved in 5% formalin. Some empty stomachs were shrunken and contained mucus, while others were expanded but completely empty; the latter type is believed to occur in fish which have recently regurgitated (Daan 1973). Regurgitated stomachs, as well as fish with food remains in their mouths, were discarded.

Gastrosomatic index (GI) and hepatosomatic index (HI) were calculated to examine monthly variations in feeding intensity and to correlate these variations with breeding cycles, using the following formulae:

Gastrosomatic index =

$$\frac{\text{Weight of gut (including contents)} \times 100}{\text{Weight of fish}}$$

$$\text{Hepatosomatic index} = \frac{\text{Weight of liver} \times 100}{\text{Weight of fish}}$$

For stomach analysis, the Index of Relative Importance (IRI) (Pinkas et al. 1971) was used. It incorporates percentage by number (N), volume (V), and frequency of occurrence (F) in the formula

$$\text{IRI} = (\%N + \%V) \times \%F.$$

The percentage IRI was calculated for the entire data set of juveniles, males, and females, and by length intervals (45 mm interval for *C. arel*, and 21 mm for *C. lida*).

Stomach contents were sorted, identified to the lowest possible taxa, and enumerated. Appendages and remains of the unidentified crustaceans are classified as "crustacean fragments." Volume of each taxonomic group of prey was measured by water displacement. To determine ontogenetic variations in feeding habits, stomach contents of juveniles were analyzed separately from those of adults.

### Age and growth

Length measurement data were grouped into size-classes at intervals of 15 mm for *C. arel* and 7 mm for *C. lida*. Percentage frequencies were calculated by month. Sexes were treated separately, to determine whether there were differences in growth patterns between males and females. The Petersen method, probability plot method, and von Bertalanffy's equation were used to determine age and growth. Attempts to detect growth layers in hard parts (scales, otoliths, opercular bones, and supraoccipital crests) were not successful.

**Petersen method** This method of growth analysis is based on the assumption that the lengths of individuals of the same age in a population are distributed normally. When there are distinct intra-annual spawning periods, the length-frequency distribution may be multimodal, representing successive age-groups. The rate of growth slows with age (Ford 1933); and as a result the modes overlap, making interpretation difficult. In the case of fishes, such as tonguefishes, which have a prolonged spawning period, various broods entering the fishery overlap. In this case, it is necessary to trace a size-group for as many months as possible after it enters the commercial fishery and to find the average monthly growth rate for different size-classes. Approximate values of average size at different ages may then be calculated.

**Probability plot method** Plots of cumulative percentages of length distribution on probability paper provide estimates of the length ranges of fish in each age-group (Harding 1949, Cassie 1954). Hence fish lengths were used to obtain an approximation of the length-at-age structure. One difficulty in this method is the uncertainty surrounding whether the deviations represent virtual inflexion points of the lines. Another difficulty is locating each inflexion point, since any

bend in the line is considered an inflexion point. Following this procedure, the line was divided into separate parts and for each (Cassie 1954), partial straight lines were drawn from which, a mean length was calculated for each age-group.

**von Bertalanffy's equation** The most widely accepted growth model is that of von Bertalanffy (1938),

$$L_t = L_\infty (1 - e^{-k(t-t_0)})$$

where  $L_t$  = length at age  $t$ ,  
 $L_\infty$  = theoretical maximum attainable (asymptotic) length,  
 $k$  = a constant, expressing the rate of change in length increments with respect to  $t$ ,  
 $t_0$  = hypothetical age at zero length, and  
 $e$  = base of Naparian or natural logarithm.

The value of  $t_0$  was calculated as follows:

$$-t_0 = 1/k [\log_e (L_\infty) - \log_e (L_\infty - L_t)] - t.$$

Walford's (1946) procedure was used to substitute  $L_t + 1$  for  $L_t$ . The equation now can be written as

$$L_t + 1 = L_\infty (1 - e^{-k}) + L_t e^{-k}.$$

### Length-weight relationship

Length-weight curves were obtained by using the equation  $W = aL^b$ . The least-squares regression of the logarithmic transformation,

$$\log_{10} W = \log_{10} a + b \log_{10} L,$$

where  $\log_{10} W = Y$ ,  $\log_{10} a = a$ ,  $\log_{10} L = X$ ,  $b = n$ , was used for estimating the values of  $a$  and  $b$  (Snedecor 1956). This linear equation was fitted separately for males, females, and unsexed juveniles of *C. arel* and *C. lida* from monthly data.

To determine whether increased weight at a given length was caused by increased gonad weight in mature fish, the length-weight relationship was compared between different stages of maturity. Adults of both sexes of *C. arel* and *C. lida* were classified into three stages (Rajaguru 1987):

**Immature** (Stage I for both sexes):  $n$  56 male and 47 female *C. arel*; 105 male and 54 female *C. lida*;

**Maturing** (Stage II for males, Stages II-III pooled for females):  $n$  221 male and 224 female *C. arel*; 259 male and 342 female *C. lida*; and

**Mature** (Stage III for males, Stages IV-VI pooled for females):  $n$  359 male and 292 female *C. arel*; 363

male and 254 female *C. lida*. (Refer to section on Reproductive biology, for Stages I-VI.)

The significance of variation in the estimate of  $b$ , from the expected value  $B (=3)$  for an ideal fish was tested by the  $t$ -test in both sexes of *C. arel* and *C. lida* (James 1967):

$$t = \frac{b-B}{S_b}$$

where  $B$  = hypothetical  $b (=3)$ , and  $S_b$  = standard error of  $b$ .

Analysis of covariance (Snedecor 1956) was used for all comparisons.

### Reproductive biology

Tonguefishes have no secondary sexual characters to distinguish the sexes. In females with gonads in advanced stages of maturity, ovaries can be seen easily through the body wall when the fish is held against light. In earlier stages of maturity, sexes are distinguishable only after dissection. Extension of gonads into body cavity, and their color, shape, and size, were noted after dissection. Ovary length was measured to the nearest mm, while weight of testis/ovary was recorded to the nearest mg. Ovaries were fixed in modified Gilson's fluid (Simpson 1951) for ova diameter studies.

To investigate the distribution pattern of ova in different regions of the ovary, ova were taken from anterior, middle, and posterior regions of eyed-side and blind-side lobes of ovaries in different stages of maturity (Clark 1934, Hickling and Rutenberg 1936, de Jong 1940). Ova diameter measurements in each part were noted separately. Results showed a uniform distribution of ovum size in different parts of both ovarion lobes. Hence to study development of ova, random samples of ~500 ova per ovary were measured from ovaries representing Stages I-VI (a total of 108 ovaries, at 18 ovaries/stage in *C. arel*, and a total of 168 ovaries, at 28 ovaries/stage in *C. lida*), using an ocular micrometer at a magnification which gave a value of  $12.5\mu$  (0.0125 mm) to each micrometer division (m.d.). Ova diameter-frequency polygons were drawn after grouping the ova into 3 m.d. (0.04 mm) class-intervals.

Spawning seasons in both species were determined from percentage occurrence of different maturity stages during various months of the year.

Generally, gonad weight depends on size and stage of gonadal development. To account for effects of differential body size on gonad size, gonad weight was expressed as a percentage of body weight (Nikolsky 1963). This ratio,

$$\frac{\text{Weight of gonad} \times 100}{\text{Weight of fish}},$$

is termed gonadosomatic index (GSI). To determine the spawning season, GSIs for various months were calculated.

Relative condition factor ( $Kn$ ) was calculated for individual fish of both sexes from the formula (Le Cren 1951),

$$Kn = W/\bar{W}$$

where,  $W$  = observed weight, and  $\bar{W}$  = calculated weight ( $\bar{W} = a+bx$ ). Monthly mean values of  $Kn$  were also calculated to confirm the spawning season.

To determine minimum length-at-first-maturity (i.e.,  $L_m$  or  $L_{50}$  = length at which 50% of fish are mature), specimens of *C. arel* and *C. lida* were grouped into 15 mm and 7 mm class-intervals, respectively. Sexes were treated separately. Percentage occurrence of immature and mature fish of various length-groups was determined, and then percentage occurrence of mature fish was plotted for both sexes.

Fecundity was determined by the gravimetric method. For this study, 26 ovaries of *C. arel* (from specimens 200-439 mm TL) and 19 of *C. lida* (161-201 mm TL) were used. Since some ova might already have been shed, ovaries with oozing ova were not used. Ovaries were removed, measured to the nearest mm, and weighed to the nearest mg. From each ovary, three subsamples (each ~50 mg) were taken and weighed after removing excess moisture, and fixed in modified Gilson's fluid. From each of these subsamples, yolked ova were separated and counted. Mean number of ova from three subsamples was multiplied by the ratio of subsample weight: ovary weight to obtain an estimation of the total number of mature ova in the ovary. Numbers of ova per mm body length, per g body weight, per mm ovary length, and per mg ovary weight were also calculated. Fecundity of *C. arel* and *C. lida* was related to total length (TL), total weight (TW), ovary length (OL), and ovary weight (OW) using linear regression. Statistical comparisons (Snedecor 1956) of fecundity to TL, TW, OL, and OW were made.

To determine the differential distribution of sexes during the spawning migration, as well as during aggregation, the sex ratio was calculated for each month. To test the homogeneity in distribution of males and females, the chi-square formula was used.

### Classification of maturity stages

Maturity stages were indexed for both sexes of *C. arel* and *C. lida*, following the ICES scale (Lovern and Wood 1937), with the following modifications. Color, shape, and extension of the ovary into the body cavity,

**Figure 2**

Percentage contribution of food items to the diet of juvenile, male, and female *Cynoglossus arel* and *C. lida* caught commercially off Porto Novo, India, October 1981–September 1982. Only values >5% IRI are individually shown; values <5% IRI are clumped together into a single category, the unshaded wedge of the pie chart. PO = polychaetes, PR = prawns; CF = crustacean fragments, FS = fish scales, AM = amphipods, CO = copepods, TN = tintinnids, FI = fishes, MI = miscellaneous.

as well as color and shape of ova, were considered to define stage of maturity in females. Degree of transparency of the ovary was also used as a criterion, since it is one of its characteristic features during early as well as fully-mature phases. Color and size of testis were used to determine the stage of maturity in males. In both species, testes were divided into four stages, and ovaries into seven stages as follows:

**Males:**

**Stage I (Immature)** Testis minute, pale white.

**Stage II (Maturing)** Testis slightly enlarged, sac-like, creamy white; no milt oozes out on pressure.

**Stage III (Mature)** Testis enlarged, sac-like, creamy white; whitish milt running from vent on slight pressure.

**Stage IV (Spent)** Not found during the present study.

**Females:**

**Stage I (Immature)** Ovary very small, thread-like and transparent; under microscope, yolkless and transparent ova seen with prominent nuclei in the center; ova invisible to naked eye.

**Stage II (Virgin maturing)** Ovary slightly thicker, translucent and yellowish; occupying 1/3 to 1/2 of body cavity; ova invisible to naked eye; under a microscope, translucent ova seen with yolk granules around nucleus.

**Stage III (Maturing)** Ovary yellowish, granular, extending to more than 1/2 the length of body cavity, with vascularization; ova small; under microscope, opaque; nucleus hidden by yolk.

**Stage IV (Mature)** Ovary creamy yellow, with

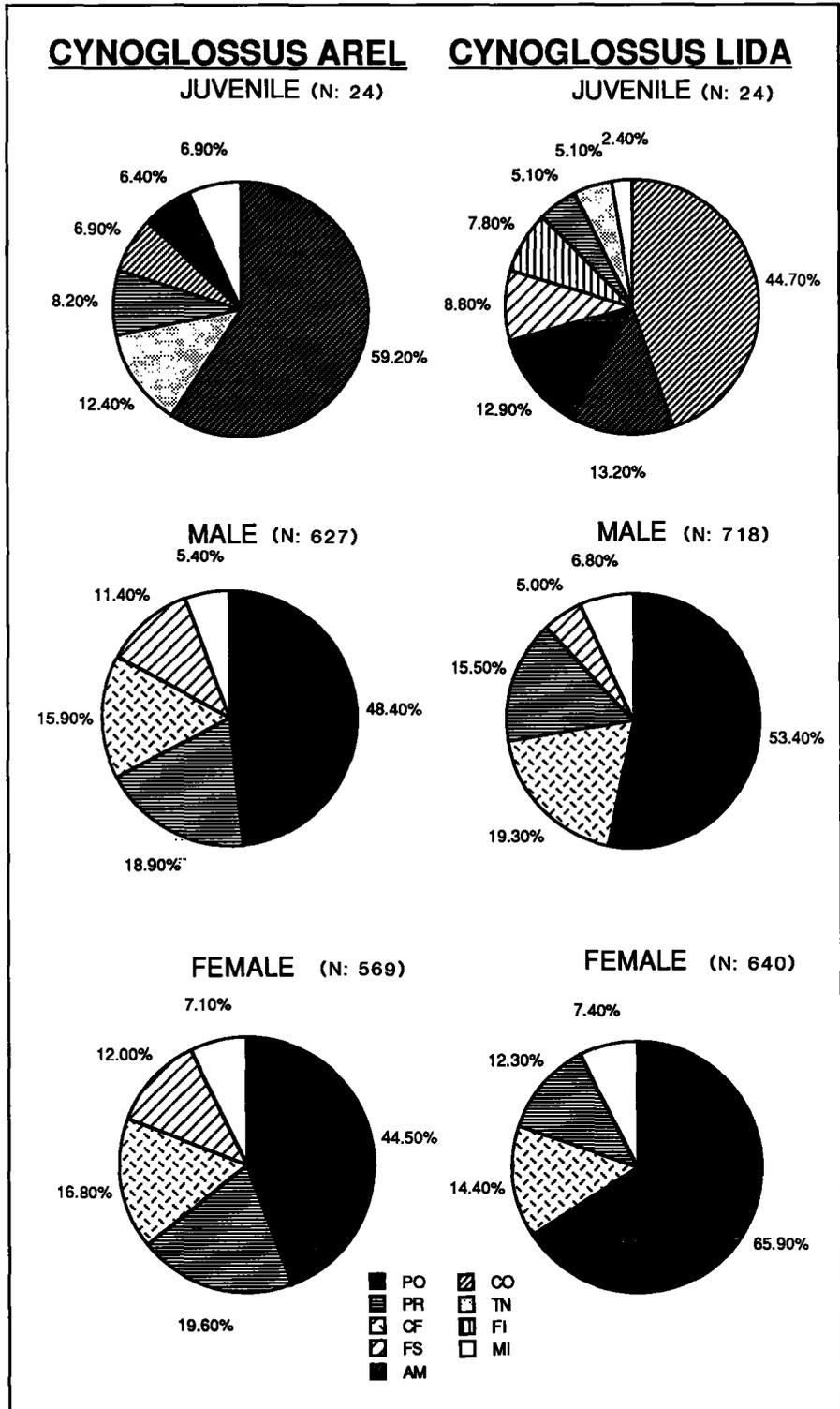


Table 1

Percent IRI of various food items of male *Cynoglossus arel* caught commercially off Porto Novo, India, October 1981–September 1982. *N* = number of stomachs analyzed; Crustacean fr. = crustacean fragments; UI = unidentified. (Data presented to one decimal point; 0.0 denotes value of <0.05, and dash denotes absence of food item.)

Food items	<i>N</i>	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	%
		53	24	54	46	56	35	69	44	56	75	86	29	627	
Polychaetes		28.0	0.3	62.2	52.4	25.2	60.4	57.9	75.6	70.1	73.2	56.1	19.1	580.5	(48.4)
Prawns		19.1	21.0	12.5	12.5	58.7	25.4	23.9	13.4	22.0	11.2	5.2	1.8	226.7	(18.9)
Crustacean fr.		23.5	15.6	14.0	25.2	10.9	9.6	8.1	3.6	0.6	4.3	4.2	70.9	190.5	(15.9)
Fish scales		26.6	53.1	10.4	2.8	1.4	2.7	2.3	1.8	4.9	3.7	26.7	0.3	136.7	(11.4)
Amphipods		0.4	0.2	0.7	1.0	3.3	0.6	7.5	5.1	0.0	2.4	2.2	3.4	26.9	(2.2)
Fish bone		1.3	—	—	—	—	—	—	—	—	—	5.2	0.6	7.1	(0.6)
Fish spine		—	5.8	—	—	0.0	—	0.0	—	—	—	—	—	5.8	(0.5)
Bivalves		0.1	0.3	0.1	0.1	0.0	0.3	0.1	0.1	0.0	4.2	0.3	—	5.7	(0.5)
<i>Lingula</i> sp.		—	—	—	5.4	0.0	—	—	—	—	—	—	0.0	5.4	(0.5)
Fishes		—	3.1	0.1	—	0.4	—	0.1	—	0.1	—	0.0	0.3	4.1	(0.3)
Crabs		0.9	0.4	0.0	0.4	0.1	0.8	0.1	0.1	0.4	0.2	0.1	—	3.6	(0.3)
Isopods		—	0.1	0.0	—	—	—	—	0.0	1.7	0.4	0.0	0.0	2.3	(0.2)
Algae		—	—	—	—	—	—	—	—	0.0	0.0	0.0	2.2	2.2	(0.2)
Fish eggs		—	—	0.0	—	—	—	—	—	0.0	0.1	—	1.3	1.4	(0.1)
Copepods		0.1	—	0.0	—	0.0	0.0	0.0	0.3	—	0.0	—	—	0.4	(0.0)
Gastropods		—	—	0.0	—	—	—	—	0.0	0.0	0.2	0.0	0.1	0.3	(0.0)
<i>Squilla</i> sp.		—	0.1	—	—	0.0	0.1	—	—	—	—	0.0	—	0.2	(0.0)
<i>Coscinodiscus</i>		—	—	—	—	—	—	—	—	0.2	—	—	—	0.2	(0.0)
Brittle star		—	—	—	0.1	—	—	0.0	—	—	—	—	—	0.1	(0.0)
Medusae		—	—	—	—	—	—	—	—	0.0	0.0	0.0	—	0.0	(0.0)
Egg mass (UI)		—	—	—	—	—	—	—	—	—	—	—	0.0	0.0	(0.0)
Nematode		0.0	—	0.0	—	—	—	0.0	0.0	—	—	—	—	0.0	(0.0)
Sand dollar		—	—	—	—	—	—	—	—	—	—	0.0	—	0.0	(0.0)
Echinoderm (UI)		—	—	—	—	—	—	—	—	0.0	—	—	—	0.0	(0.0)

prominent blood vessels; occupying 2/3 of body cavity; ova visible to naked eye and rich with yolk.

**Stage V (Ripe)** Ovary resembling Stage IV, but occupying more than 2/3 of the body cavity; under a microscope, ova slightly translucent with yolk granules; ova not running out of genital aperture on application of gentle pressure.

**Stage VI (Oozing)** Ovary yellowish and transparent, occupying entire length of body cavity; ripe ova running out through genital aperture on application of gentle external pressure on ovary; under a microscope, ova transparent.

**Stage VII (Spent)** Not found during the study.

## Results

### Feeding ecology

**Food composition** In *Cynoglossus arel*, polychaetes made up the bulk (44.5–48.4% IRI) of the diet of adults (Tables 1–2, Fig. 2). At least 11 species of polychaetes, viz, *Nephtys polybranchia*, *N. oligobranchia*, *Clymene annandalei*, *Phyllodoce* sp., *Ancistrosyllis constricta*, *Nereis chilkaensis*, *Diopatra* sp., *Onuphis* sp., *Eunice*

sp., *Terebellides stroemi*, and *Sternaspis* sp., were consumed. The next most important prey items were prawns (18.9–19.6% IRI), crustacean fragments (15.9–16.8% IRI), and fish scales (11.4–12.0% IRI). The prey species which were consumed in smaller quantities included bivalves (represented by *Amussium* sp., *Placenta* sp., *Arca* sp., and *Pinna* sp.), gastropods (by *Umboonium* sp., *Turritella* sp., and *Dentalium* sp.), and fishes (by gobiids and *Cynoglossus monopus*) (Tables 1–2).

In adult *C. lida*, polychaetes (same species as in *C. arel*) dominated (53.4–65.9% IRI) (Tables 3–4, Fig. 2), while crustacean fragments (14.4–19.3% IRI) and prawns (12.3–15.5% IRI) ranked next in importance. The prey species which were consumed in smaller quantities included bivalves (represented by *Placenta* sp.), gastropods (by *Umboonium* sp. and *Turritella* sp.), and fishes (by gobiids and *Cynoglossus monopus*) (Tables 3–4).

**Food of juveniles and adults** Differences can be seen in stomach contents between juveniles and adults of both species (Tables 1–5, Fig. 2). Larger tonguefishes ate larger individuals of food species than did

Table 2

Percent IRI of various food items of female *Cynoglossus arel* caught commercially off Porto Novo, India, October 1981–September 1982. See Table 1 for abbreviations.

Food items	N	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	%
		39	45	49	55	54	40	56	54	35	54	54	34	569	
Polychaetes		4.6	10.7	25.2	74.4	19.6	36.4	60.7	71.9	71.6	72.9	37.4	48.3	533.7	(44.5)
Prawns		30.8	17.9	26.4	9.5	41.0	41.1	19.0	3.3	10.8	14.3	12.7	8.7	235.5	(19.6)
Crustacean fr.		28.0	35.1	25.4	11.8	33.6	17.6	5.1	2.1	4.6	2.4	7.6	28.7	202.0	(16.8)
Fish scales		21.6	23.2	14.3	2.0	0.7	1.5	8.0	20.9	1.1	9.0	40.5	0.7	143.5	(12.0)
Amphipods		0.2	0.7	1.3	1.4	2.1	1.8	5.4	0.9	—	0.3	0.8	3.2	18.1	(1.5)
Fish bone		13.9	—	—	—	—	—	—	—	—	0.2	0.0	—	14.1	(1.2)
Fish spine		—	7.9	2.6	—	—	—	0.0	0.0	—	—	—	—	10.5	(0.9)
Crabs		0.7	0.0	1.6	0.2	2.6	1.4	0.1	0.0	0.7	0.1	0.4	2.6	10.4	(0.9)
Isopods		0.1	—	0.0	—	—	0.0	0.0	0.0	7.3	0.0	—	0.0	7.4	(0.6)
Fish eggs		—	0.0	—	—	—	—	—	—	—	0.0	0.0	6.1	6.1	(0.5)
Bivalves		0.1	1.6	1.0	0.1	0.0	0.0	0.0	0.0	1.7	0.1	0.2	0.5	5.3	(0.4)
Fishes		—	2.3	0.4	—	—	0.1	0.4	0.9	0.7	0.1	0.2	—	5.1	(0.4)
<i>Lingula</i> sp.		—	—	1.8	0.6	—	—	—	0.0	—	—	—	—	2.4	(0.2)
Gastropods		0.0	—	0.0	0.0	0.0	—	—	—	1.2	0.0	0.1	0.7	2.0	(0.2)
<i>Lucifer</i>		—	—	—	—	—	—	1.2	—	0.0	—	—	0.1	1.3	(0.1)
Copepods		—	0.6	—	—	0.4	—	0.0	0.0	—	0.0	—	0.0	1.0	(0.1)
Ciliates (UI)		—	—	—	—	—	—	—	—	—	0.5	—	—	0.5	(0.0)
Algae		—	—	—	—	—	—	—	—	0.0	0.0	0.0	0.4	0.4	(0.0)
<i>Coscinodiscus</i>		—	—	—	—	—	—	—	—	0.3	—	—	—	0.3	(0.0)
<i>Squilla</i> sp.		—	—	—	0.0	0.0	—	0.0	—	—	—	0.1	0.0	0.1	(0.0)
Brittle star		—	—	—	—	—	—	—	0.0	—	0.1	—	—	0.1	(0.0)
Medusae		—	—	—	—	—	—	0.1	—	0.0	—	—	—	0.1	(0.0)
Sand dollar		—	—	—	—	—	0.1	—	—	—	—	—	—	0.1	(0.0)
Nematode		0.0	0.0	0.0	—	0.0	—	—	0.0	—	—	—	0.0	0.0	(0.0)
Egg mass (UI)		—	—	—	0.0	—	—	—	0.0	—	—	0.0	0.0	0.0	(0.0)
Tube-like worm		—	—	—	—	—	—	—	—	0.0	—	—	—	0.0	(0.0)
Jelly fish		—	—	—	—	—	—	0.0	—	—	—	—	—	0.0	(0.0)
<i>Sepia</i>		—	—	—	—	—	0.0	—	—	—	—	—	—	0.0	(0.0)

smaller tonguefishes. In *C. arel*, amphipods (59.2% IRI) dominated diets of juveniles, followed by tintinnids (12.4% IRI). Smaller-sized prawns (8.2% IRI), copepods (6.9% IRI), and polychaetes (6.4% IRI) were next in importance. Fish remains, isopods, smaller crabs, and nematodes were found in decreasing order of importance and never composed more than 5% of the IRI. Breadth of the diet is much smaller in juveniles than adults (compare Tables 1–4 and 5). Only 10 types of food items occurred in stomachs of relatively few juveniles examined, whereas 29 different types of prey were noted in stomachs of adult *C. arel* (Tables 1–2, 5). In adult stomachs, fewer amphipods and more polychaetes were found than in juvenile stomachs. Prawns were the third most important prey in the diet of the juveniles, whereas in adults they were the second most important. Algal filaments were found only in stomachs of adults, while tintinnids were found only in stomachs of juveniles.

Juvenile *C. lida* fed on only 10 types of prey items and usually smaller sizes, whereas adults consumed 24

types of relatively large-sized prey items (Tables 3–5). Copepods (44.7% IRI) were preyed upon predominantly by juveniles of *C. lida* (Fig. 2), while polychaetes were dominant in the diet of adults. Hyperiid amphipods (13.2% IRI), which were of secondary importance and abundant in the diet of juveniles, occurred in smaller quantities in adult stomachs. Crustacean fragments were the second most important food item for adults. Other food items of juveniles are listed in Table 5.

However, the sample sizes for the juveniles of both tonguefishes are quite smaller than those of the adults. Therefore, the differences in number of prey in adults and juveniles may reflect differences in sample sizes.

**Food of males and females** A total of 76% of males and females of *C. arel*, and 65% of males and 73% of females of *C. lida*, had identifiable prey in their stomachs. In *C. lida*, females consumed 19 types of food items and males consumed 24 types (Tables 3–4). Polychaetes were relatively more abundant (Fig. 2) in the diet of females than males (65.9% vs. 53.4% IRI).

**Table 3**

Percent IRI of various food items of male *Cynoglossus lida* caught commercially off Porto Novo, India, October 1981–September 1982. See Table 1 for abbreviations.

Food items	N	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	%
		32	59	64	84	38	56	25	43	46	83	160	28	718	
Polychaetes		5.4	42.3	31.2	89.4	21.4	67.6	27.8	93.8	87.4	83.0	89.2	2.8	641.3	(53.4)
Crustacean fr.		64.5	12.6	26.4	1.0	16.5	4.9	18.2	0.1	2.5	0.7	1.6	83.1	232.1	(19.3)
Prawns		17.5	9.6	26.6	3.8	57.3	21.5	23.3	3.6	8.0	6.2	5.1	3.8	186.3	(15.5)
Fish scales		6.4	20.4	12.7	0.8	2.7	0.2	3.8	0.2	0.5	6.5	0.6	5.2	60.0	(5.0)
Amphipods		0.6	2.4	0.2	3.2	1.9	5.7	24.7	2.0	—	3.4	3.3	0.2	47.6	(4.0)
Algae		5.2	4.3	—	—	—	—	—	0.0	0.0	—	—	4.4	13.9	(1.2)
Medusae		—	8.3	—	—	—	—	—	—	—	—	0.0	—	8.3	(0.7)
<i>Lucifer</i>		0.0	—	—	—	0.1	—	2.1	—	0.1	—	—	—	2.3	(0.2)
Copepods		0.0	—	2.0	0.0	—	—	—	0.0	0.0	—	—	0.1	2.1	(0.2)
<i>Lingula</i> sp.		—	0.0	0.2	1.6	—	—	—	—	—	—	0.0	—	1.8	(0.2)
Crabs		—	0.1	0.4	0.1	0.1	0.1	—	0.1	0.0	—	0.0	0.1	1.0	(0.1)
Isopods		0.3	0.0	0.3	—	—	—	—	—	0.3	—	—	0.0	0.9	(0.1)
Fishes		—	—	—	0.1	—	—	—	—	0.7	—	—	—	0.8	(0.1)
Fish eggs		0.1	0.1	—	—	—	—	—	—	—	—	—	0.3	0.5	(0.0)
Gastropods		—	0.0	—	—	—	—	—	0.1	0.2	—	0.1	—	0.4	(0.0)
<i>Coscinodiscus</i>		—	—	—	—	—	—	—	—	0.3	—	—	—	0.3	(0.0)
Bivalves		—	0.0	—	—	—	—	—	0.1	0.0	0.2	0.1	—	0.4	(0.0)
Nematode		0.0	0.0	—	—	—	—	—	—	0.0	—	—	0.0	0.0	(0.0)
Brittle star		—	—	—	0.0	—	—	—	—	—	—	—	—	0.0	(0.0)
<i>Squilla</i> sp.		—	0.0	—	—	—	—	—	—	—	—	0.0	—	0.0	(0.0)
Fish spine		—	—	—	0.0	—	—	—	—	—	—	0.0	—	0.0	(0.0)
<i>Octopus</i> sp.		—	0.0	—	—	—	—	—	—	—	—	—	—	0.0	(0.0)
Tape worm		—	—	—	0.0	—	—	—	—	—	—	—	—	0.0	(0.0)
Egg mass (UI)		—	0.0	—	—	—	—	—	—	—	—	—	—	0.0	(0.0)

**Table 4**

Percent IRI of various food items of female *Cynoglossus lida* caught commercially off Porto Novo, India, October 1981–September 1982. See Table 1 for abbreviations.

Food items	N	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	%
		42	16	18	51	31	59	25	62	25	76	207	28	640	
Polychaetes		17.7	58.8	58.1	84.5	60.8	73.4	63.3	95.0	93.4	87.9	94.2	4.0	791.1	(65.9)
Crustacean fr.		48.5	12.5	7.7	2.0	5.2	5.0	10.3	0.6	1.2	0.8	0.3	78.7	172.8	(14.4)
Prawns		26.5	13.6	17.3	7.6	31.3	20.3	16.7	1.8	2.9	4.2	2.5	2.5	147.2	(12.3)
Amphipods		0.3	12.0	8.2	4.1	2.4	0.9	7.9	2.6	—	0.9	2.8	0.0	42.1	(3.5)
Fish scales		4.4	—	1.2	0.0	0.2	0.4	1.4	0.0	—	6.0	0.0	2.6	16.2	(1.4)
Fish eggs		0.4	0.1	0.3	—	—	—	—	—	0.9	—	—	7.5	9.2	(0.8)
<i>Lingula</i> sp.		—	—	6.7	1.8	—	—	—	0.0	—	—	—	—	8.5	(0.7)
Algae		1.3	1.2	—	—	—	—	—	—	—	—	—	4.6	7.1	(0.6)
Crabs		0.1	1.0	—	—	0.1	—	—	0.0	—	—	0.0	0.1	1.3	(0.1)
Isopods		0.0	0.1	0.2	0.0	0.0	0.0	—	—	0.9	0.1	0.0	—	1.3	(0.1)
Bivalves		0.3	—	—	—	—	0.0	0.3	—	0.3	0.1	0.2	—	1.2	(0.1)
<i>Squilla</i> sp.		0.1	0.5	—	—	—	0.0	—	—	—	—	—	—	0.6	(0.1)
Nematode		0.3	0.1	—	—	—	—	—	—	0.0	0.0	0.0	0.0	0.4	(0.0)
Copepods		0.0	—	0.2	—	—	0.0	0.1	—	—	0.0	0.0	—	0.3	(0.0)
Gastropods		0.0	0.1	—	—	—	—	—	—	0.3	—	0.0	—	0.4	(0.0)
<i>Coscinodiscus</i>		—	—	0.1	—	—	—	—	—	0.1	—	—	—	0.2	(0.0)
Medusae		0.1	—	—	—	—	—	—	—	—	—	—	—	0.1	(0.0)
Egg mass (UI)		0.0	—	—	—	—	—	—	—	—	—	—	—	0.0	(0.0)
Fish spine		—	—	—	—	—	—	—	0.0	—	—	—	—	0.0	(0.0)

**Table 5**

Percent IRI of various food items of juvenile *Cynoglossus arel* and *C. lida* caught commercially off Porto Novo, India, October 1981–September 1982. See Table 1 for abbreviations. (Data presented to one decimal point; dash denotes absence of food item.)

Food items	N	<i>C. arel</i>					<i>C. lida</i>					
		Mar.	June	Oct.	Nov.	Total	Apr.	Nov.	Dec.	Total		
		6	5	7	6	24	8	9	7	24	%	
Amphipods		50.0	83.0	60.4	43.5	236.9	(59.2)	3.0	32.8	3.9	39.7	(13.2)
Copepods		7.6	—	0.1	19.9	27.6	(06.9)	75.9	1.7	56.4	134.0	(44.7)
Tintinnids		11.1	—	16.4	21.9	49.4	(12.4)	—	12.0	3.3	15.3	(5.1)
Polychaetes		17.1	8.5	—	—	25.6	(6.4)	13.3	18.7	6.7	38.7	(12.9)
Prawns		—	1.3	20.4	10.9	32.6	(8.2)	2.5	12.7	—	15.2	(5.1)
Fish scales		1.0	1.6	1.2	3.0	6.8	(1.7)	1.7	18.4	6.3	26.4	(8.8)
Fishes		—	—	—	—	—	—	—	—	23.4	23.4	(7.8)
Crustacean fr.		11.1	5.1	—	—	16.2	(4.1)	—	0.8	—	0.8	(0.3)
Isopods		2.2	—	0.8	0.8	3.8	(1.0)	—	—	—	—	—
Ciliates (UI)		—	—	—	—	—	—	3.6	—	—	3.6	(1.2)
Nematode		—	0.3	0.1	0.1	0.5	(0.1)	—	3.0	—	3.0	(1.0)
Crabs		—	—	0.6	—	0.6	(0.2)	—	—	—	—	—

In *C. arel*, males consumed 24 types of food and females had 28 types of prey (Tables 1–2). Polychaetes were slightly more important in diets of males (48.4% IRI) than in females (44.5% IRI) (Tables 1–2, Fig. 2).

The difference in numbers of identified prey in males and females is due to rare species occurring in some individuals.

**Table 6**

Percent frequency of occurrence (%F), percent of total number (%N), percent of total volume (%V), and index of relative importance (IRI) for food items of male and female *Cynoglossus arel* caught off Porto Novo, India, October 1981–September 1982. Size groups: 95–139 mm TL (*n* 10 ♂, *n* 15 ♀), and 140–184 mm TL (*n* 122 ♂, *n* 96 ♀) combined. *n* = number of stomachs analyzed; Crustacean fr. = crustacean fragments; UI = unidentified. (Data presented to one decimal point; 0.0 denotes value of <0.05, and dash denotes absence of food item.)

Food items	Male ( <i>n</i> 132)					Female ( <i>n</i> 111)				
	%F	%V	%N	IRI	%IRI	%F	%V	%N	IRI	%IRI
Polychaetes	27.7	62.8	30.7	2590.0	66.3	24.8	52.7	27.8	1996.4	62.7
Crustacean fr.	15.8	12.5	24.4	583.0	15.0	16.1	15.0	31.5	748.7	23.5
Prawns	14.9	15.9	10.4	391.9	10.0	11.2	10.7	7.5	203.8	6.4
Fish scales	10.9	1.7	17.0	203.8	5.2	9.9	0.4	3.8	41.6	1.3
Amphipods	12.4	0.9	8.6	117.8	3.1	11.8	0.7	7.5	96.8	3.0
Bivalves	2.0	1.5	1.4	5.8	0.2	3.8	2.2	2.3	17.1	0.5
Gastropods	2.0	0.1	0.6	1.4	0.0	2.5	0.2	1.5	4.3	0.1
Isopods	1.5	0.5	0.5	1.5	0.0	1.2	0.4	0.4	1.0	0.0
Copepods	1.5	0.0	0.6	0.9	0.0	2.5	0.0	1.3	3.3	0.1
Crabs	1.5	0.6	0.5	1.7	0.0	3.2	2.1	1.5	11.5	0.4
Fish	0.5	2.0	0.2	1.1	0.0	1.2	11.9	1.0	15.5	0.5
Fish bone	0.5	0.0	0.2	0.1	0.0	—	—	—	—	—
Fish spine	1.0	0.0	0.5	0.5	0.0	—	—	—	—	—
Fish egg	1.9	0.1	1.1	2.3	0.1	3.8	0.4	7.7	30.8	1.0
<i>Squilla</i>	—	—	—	—	—	0.6	0.0	0.2	0.1	0.0
<i>Lingula</i> sp.	1.0	0.5	1.1	1.6	0.0	1.2	1.5	2.9	5.3	0.2
Nematode	0.5	0.0	0.2	0.1	0.0	1.2	0.1	0.8	1.1	0.0
Algae	2.4	0.1	1.1	2.9	0.1	3.1	0.1	1.3	4.3	0.1
Brittle star	1.0	0.4	0.5	0.9	0.0	—	—	—	—	—
Echinoderm (UI)	0.5	0.2	0.2	0.2	0.0	—	—	—	—	—
Egg mass (UI)	0.5	0.2	0.2	0.2	0.0	—	—	—	—	—
<i>Lucifer</i>	—	—	—	—	—	1.9	1.6	1.0	4.9	0.2

**Table 7**

Percent frequency of occurrence (%F), percent of total number (%N), percent of total volume (%V), and index of relative importance (IRI) for food items of male and female *Cynoglossus arel* caught off Porto Novo, India, October 1981–September 1982. Size group: 185–229 mm TL ( $n$  338 ♂,  $n$  229 ♀). See Table 6 for abbreviations.

Food items	Male ( $n$ 338)					Female ( $n$ 229)				
	%F	%V	%N	IRI	%IRI	%F	%V	%N	IRI	%IRI
Polychaetes	28.2	57.5	30.5	2481.6	60.5	22.2	58.8	33.6	2051.3	58.8
Prawns	19.3	25.6	18.1	843.4	20.5	20.7	22.1	16.8	805.2	23.1
Crustacean fr.	14.7	8.6	18.2	394.0	9.6	14.2	7.9	18.0	367.8	10.5
Fish scales	13.6	1.7	18.1	269.3	6.6	12.4	0.6	7.1	95.5	2.8
Amphipods	11.6	0.7	7.3	92.8	2.3	12.4	0.8	9.3	125.2	3.6
Bivalves	3.3	1.4	1.5	9.6	0.2	2.3	3.5	4.0	17.3	0.5
Gastropods	0.4	0.0	0.1	0.0	0.0	1.2	0.3	2.6	3.5	0.1
Isopods	1.5	0.5	0.4	1.4	0.0	1.6	0.5	0.6	1.8	0.1
Copepods	1.3	0.0	0.4	0.5	0.0	1.2	0.0	0.3	0.4	0.0
Crabs	3.1	1.5	1.0	7.8	0.2	3.5	1.8	1.3	10.9	0.3
Fish	0.2	0.6	0.1	0.1	0.0	0.4	1.2	0.1	0.5	0.0
Fish egg	0.7	0.0	0.4	0.3	0.0	1.4	0.1	3.3	4.8	0.1
<i>Squilla</i>	—	—	—	—	—	0.4	0.2	0.1	0.1	0.0
<i>Lingula</i> sp.	0.6	1.6	3.4	3.0	0.1	0.8	0.2	0.5	0.5	0.0
Nematode	0.2	0.0	0.1	0.0	0.0	0.4	0.0	0.1	0.0	0.0
Algae	0.7	0.0	0.2	0.1	0.0	1.0	0.0	0.6	0.5	0.0
Egg mass (UI)	—	—	—	—	—	0.4	0.1	0.1	0.1	0.0
<i>Lucifer</i>	—	—	—	—	—	1.9	0.9	0.7	3.0	0.1
Sepia	—	—	—	—	—	0.2	0.1	0.1	0.0	0.0
Sand dollar	—	—	—	—	—	0.2	0.5	0.1	0.1	0.0
Tube-like worm	0.6	0.3	0.2	0.3	0.0	0.8	0.2	0.3	0.4	0.0
Jelly fish	—	—	—	—	—	0.2	0.1	0.1	0.0	0.0
<i>Coscinodiscus</i>	—	—	—	—	—	0.2	0.0	0.3	0.1	0.0

**Food vs. fish size** In *C. arel*, the dominant size-group in both sexes is 185–229 mm TL (54% of males, and 40% of females). Females in this size-group had eaten 23 types of prey, while males consumed only 16 types (Table 7). In the remaining size-groups of both sexes, there is no obvious difference in the number of prey types consumed (Tables 6, 8–9). In both sexes of *C. arel*, fish <275 mm TL preyed predominantly on polychaetes (55.1–66.3% IRI in males, 53.4–62.7% IRI in females), whereas in fish >275 mm TL the polychaetes were of lesser importance (10.5% IRI in females, <5.0% IRI in males), with fish remains being the most abundant (54.5% IRI in males, and 48.9% IRI in females) (Tables 6–9, and Fig. 3).

In both sexes of *C. lida*, fewer prey types were consumed by fish >200 mm TL (8–9 prey types) and by fish <136 mm TL (10–13 types), compared with fish 137–199 mm TL (16–19 types). Among fish <200 mm TL, polychaetes were the most abundant prey in both sexes (67.2–89.0% IRI in females, 61.0–81.5% IRI in males) (Tables 10–13, Fig. 4). Among the fish >200 mm TL, polychaetes were the most abundant prey only in females (90.2% IRI), whereas polychaetes were the second-most important prey in males (28.2% IRI) and prawns the most abun-

dant prey (52.6% IRI) (Table 14, Fig. 4).

**Seasonal variations in diet composition** In male *C. arel*, polychaetes were dominant, except in February, May, and December (Table 1). During these 3 months, other prey items, viz, prawns (in May), crustacean fragments (in December), and fish remains (in February) were more important in the diet. In females, polychaetes also formed the primary food during 6 months (April, July, August, September, October, and December). In other months, prawns (January, March, May, and June), crustacean fragments (February), and fish remains (November) were the primary food consumed (Table 2).

In male *C. arel*, prawns were the secondary prey item for 6 months (February, June, July, August, September, and October), with polychaetes in May and December, crustacean fragments in March and April, and fish remains in January and November. In females, crustacean fragments were the secondary prey item for 5 months (January, March, April, May, and December), prawns for 3 months (July, September, and October), polychaetes for 2 months (June and November), and fish remains for 2 months (February and August). The tertiary food group in the diet of

**Table 8**

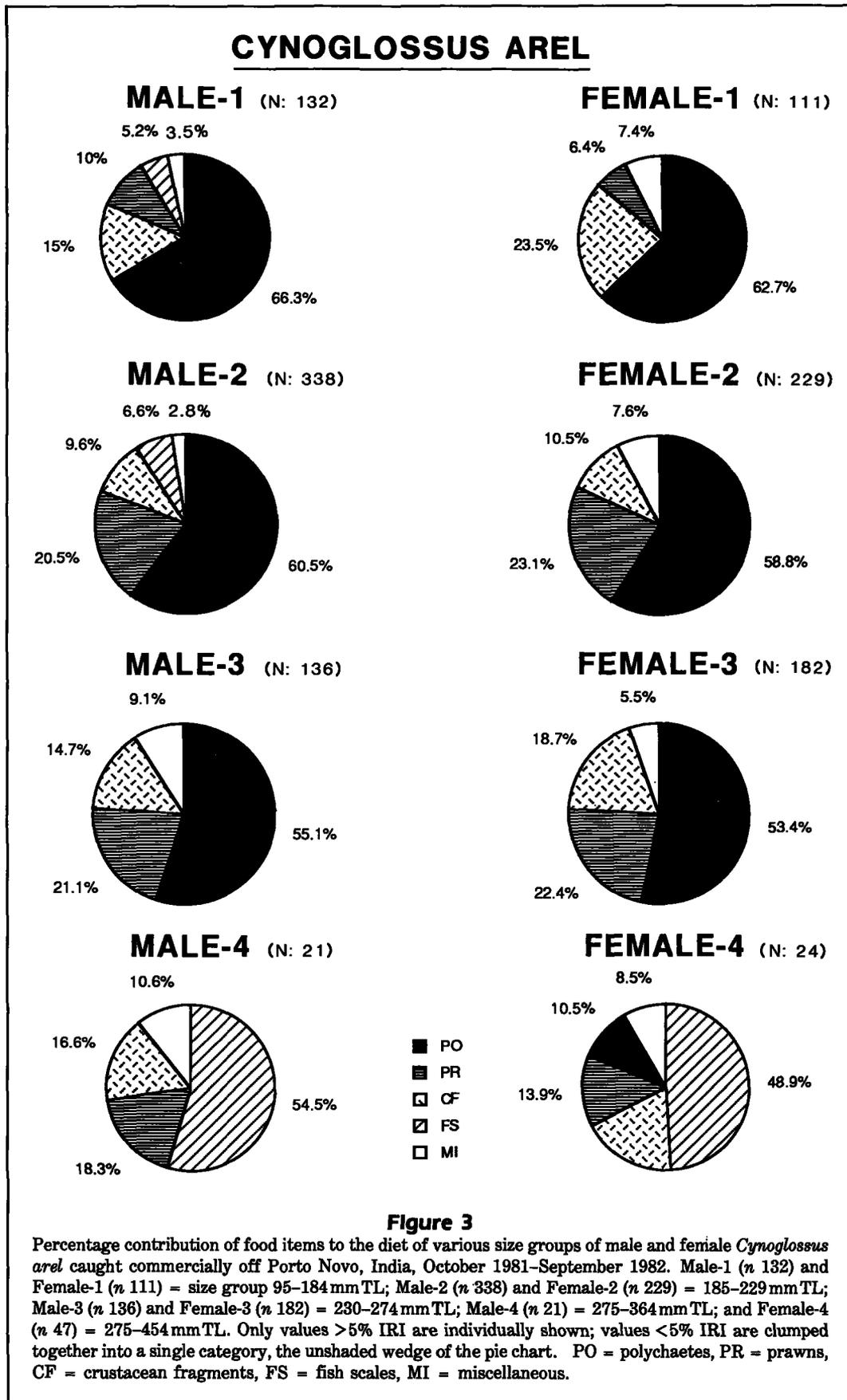
Percent frequency of occurrence (%F), percent of total number (%N), percent of total volume (%V), and index of relative importance (IRI) for food items of male and female *Cynoglossus arel* caught off Porto Novo, India, October 1981–September 1982. Size group: 230–274 mm TL (*n* 136 ♂, *n* 182 ♀). See Table 6 for abbreviations.

Food items	Male ( <i>n</i> 136)					Female ( <i>n</i> 182)				
	%F	%V	%N	IRI	%IRI	%F	%V	%N	IRI	%IRI
Polychaetes	23.2	46.8	21.7	1589.2	55.1	23.7	50.1	25.8	1798.8	53.4
Prawns	18.8	20.0	12.4	609.1	21.1	18.0	24.9	17.0	756.0	22.4
Crustacean fr.	14.8	10.0	18.6	423.3	14.7	17.3	11.9	24.5	629.7	18.7
Fish scales	10.3	0.5	3.6	42.2	1.5	10.7	0.5	4.9	57.8	1.7
Amphipods	11.8	1.1	6.3	87.3	3.0	10.5	0.4	3.8	44.1	1.3
Bivalves	3.3	3.0	2.8	19.1	0.7	2.7	1.0	1.0	5.4	0.2
Gastropods	2.6	0.1	0.6	1.8	0.1	1.6	0.0	0.3	0.5	0.0
Isopods	1.8	1.3	1.2	4.5	0.2	1.8	0.8	0.8	2.9	0.1
Copepods	1.5	0.0	0.3	0.5	0.0	—	—	—	—	—
Crabs	3.7	2.2	1.3	13.0	0.4	5.9	5.5	3.8	54.9	1.6
Fish	1.5	3.9	0.3	6.3	0.2	0.9	2.0	0.2	2.0	0.1
Fish bone	2.2	9.6	29.7	86.5	3.0	0.2	0.0	0.1	0.0	0.0
Fish spine	—	—	—	—	—	0.9	0.1	0.5	0.5	0.0
Fish egg	0.7	0.0	0.2	0.1	0.0	0.9	0.1	1.4	1.4	0.0
<i>Squilla</i>	1.1	0.6	0.2	0.9	0.0	0.9	0.5	0.3	0.7	0.0
<i>Lingula</i> sp.	0.4	0.0	0.1	0.0	0.0	0.9	1.3	3.0	3.9	0.1
Nematode	0.4	0.0	0.1	0.0	0.0	0.5	0.0	0.1	0.1	0.0
Algae	1.1	0.0	0.4	0.0	0.0	0.5	0.1	0.2	0.2	0.0
Egg mass (UI)	—	—	—	—	—	0.9	0.1	11.8	10.7	0.4
<i>Lucifer</i>	—	—	—	—	—	0.5	0.1	0.1	0.1	0.0
Sand dollar	0.4	0.8	0.1	0.4	0.0	—	—	—	—	—
Tube-like worm	0.4	0.1	0.1	0.1	0.0	—	—	—	—	—
<i>Coscinodiscus</i>	—	—	—	—	—	0.2	0.0	0.1	0.0	0.0
Brittle star	—	—	—	—	—	0.5	0.6	0.3	0.5	0.0

**Table 9**

Percent frequency of occurrence (%F), percent of total number (%N), percent of total volume (%V), and index of relative importance (IRI) for food items of male and female *Cynoglossus arel* caught off Porto Novo, India, October 1981–September 1982. Size groups: 275–319 mm TL (*n* 12 ♂, *n* 24 ♀); 320–364 mm TL (*n* 9 ♂, *n* 8 ♀); 365–409 mm TL (*n* 0 ♂, *n* 9 ♀), and 410–454 mm TL (*n* 0 ♂, *n* 6 ♀) combined. See Table 6 for abbreviations.

Food items	Male ( <i>n</i> 21)					Female ( <i>n</i> 47)				
	%F	%V	%N	IRI	%IRI	%F	%V	%N	IRI	%IRI
Fish scales	13.9	31.2	66.3	1355.3	54.5	15.3	23.4	60.8	1288.3	48.9
Prawns	20.8	19.2	2.7	455.5	18.3	18.5	16.9	2.9	366.3	13.9
Crustacean fr.	25.0	11.6	4.9	412.5	16.6	16.1	19.6	10.2	479.8	18.2
Polychaetes	11.1	8.4	0.9	103.2	4.2	14.5	16.9	2.2	277.0	10.5
Amphipods	5.6	4.5	0.2	26.3	1.1	4.0	0.1	0.2	1.2	0.0
Bivalves	—	—	—	—	—	3.3	0.5	0.1	2.0	0.1
Gastropods	—	—	—	—	—	1.6	0.0	0.0	0.0	0.0
Isopods	4.2	0.7	0.2	3.8	0.2	0.8	0.1	0.0	0.1	0.0
Copepods	—	—	—	—	—	1.6	0.1	3.0	5.0	0.2
Crabs	5.5	1.5	0.2	9.4	0.0	6.5	2.0	0.3	15.0	0.6
Fish	4.2	10.1	0.2	43.3	1.8	7.3	10.8	0.3	81.0	3.1
Fish bone	1.4	5.0	10.8	22.1	1.0	2.4	0.1	0.1	0.5	0.0
Fish spine	2.7	7.5	12.7	54.5	2.2	4.0	9.5	19.8	117.2	4.5
Fish egg	—	—	—	—	—	0.8	0.0	0.0	0.0	0.0
<i>Squilla</i>	1.4	0.3	0.0	0.4	0.0	—	—	—	—	—
Nematode	1.4	0.0	0.0	0.0	0.0	3.3	0.0	0.1	0.3	0.0
Algae	1.4	0.0	0.0	0.0	0.0	—	—	—	—	—
<i>Coscinodiscus</i>	1.4	0.0	0.9	1.3	0.1	—	—	—	—	—



**Table 10**

Percent frequency of occurrence (%F), percent of total number (%N), percent of total volume (%V), and index of relative importance (IRI) for food items of male and female *Cynoglossus lida* caught off Porto Novo, India, October 1981–September 1982. Size groups: 95–115 mm TL ( $n$  6 ♂,  $n$  13 ♀), and 116–136 mm TL ( $n$  85 ♂,  $n$  56 ♀) combined.  $n$  = number of stomachs analyzed; Crustacean fr. = crustacean fragments. (Data presented to one decimal point; 0.0 denotes value of <0.05, and dash denotes absence of food item.)

Food items	Male ( $n$ 91)					Female ( $n$ 69)				
	%F	%V	%N	IRI	%IRI	%F	%V	%N	IRI	%IRI
Polychaetes	29.0	73.4	42.6	3364.0	81.5	30.4	66.2	35.4	3088.6	70.2
Prawns	16.9	10.9	8.5	327.9	8.0	17.4	13.8	9.9	412.4	9.4
Crustacean fr.	8.9	8.4	19.6	249.2	6.1	13.0	16.2	34.5	659.1	15.0
Fish scales	13.0	0.8	9.0	22.1	0.5	10.9	0.4	4.3	51.2	1.2
Amphipods	13.0	0.6	6.7	94.9	2.3	17.4	0.8	8.1	154.9	3.5
Bivalves	—	—	—	—	—	1.1	0.3	0.3	0.7	0.0
Isopods	1.6	0.5	0.5	1.6	0.0	1.1	0.3	0.3	0.7	0.0
Copepods	1.6	0.0	0.5	0.8	0.0	—	—	—	—	—
Crabs	2.4	1.7	1.3	7.2	0.2	—	—	—	—	—
Fish egg	2.4	0.1	1.3	3.4	0.1	1.1	0.0	0.9	1.0	0.0
<i>Lingula</i> sp.	4.0	2.2	5.0	28.8	0.7	3.3	1.9	4.1	19.8	0.5
Algae	5.6	0.2	4.2	24.6	0.6	4.3	0.1	2.2	9.9	0.2
<i>Lucifer</i>	0.8	0.3	0.3	0.5	0.0	—	—	—	—	—
Brittle star	0.8	0.9	0.5	1.1	0.0	—	—	—	—	—

**Table 11**

Percent frequency of occurrence (%F), percent of total number (%N), percent of total volume (%V), and index of relative importance (IRI) for food items of male and female *Cynoglossus lida* caught off Porto Novo, India, October 1981–September 1982. Size group: 137–157 mm TL ( $n$  211 ♂,  $n$  136 ♀). See Table 10 for abbreviations.

Food items	Male ( $n$ 211)					Female ( $n$ 136)				
	%F	%V	%N	IRI	%IRI	%F	%V	%N	IRI	%IRI
Polychaetes	25.5	61.7	28.4	2297.6	61.0	30.0	62.0	29.9	2757.0	67.2
Crustacean fr.	15.3	16.7	30.7	725.2	19.2	15.5	16.5	31.8	748.7	18.3
Prawns	15.6	13.6	8.3	341.6	9.1	14.5	17.0	10.9	404.6	9.9
Fish scales	16.3	1.4	12.8	231.5	6.1	11.4	0.5	5.2	65.0	1.6
Amphipods	12.3	1.1	10.5	142.7	3.9	13.6	0.6	5.5	83.0	2.0
Bivalves	1.8	0.8	0.7	2.7	0.1	1.8	0.7	0.7	2.5	0.1
Gastropods	0.3	0.0	0.1	0.0	0.0	0.9	0.0	0.2	0.2	0.0
Isopods	0.9	0.4	0.4	0.7	0.0	1.4	0.4	0.4	1.1	0.0
Copepods	0.9	0.0	0.6	0.5	0.0	0.9	0.0	0.3	0.3	0.0
Crabs	1.3	0.7	0.4	1.4	0.0	0.9	0.7	0.5	1.1	0.0
Fish	0.3	1.1	0.1	0.4	0.0	—	—	—	—	—
Fish spine	0.3	0.0	0.2	0.1	0.0	—	—	—	—	—
Fish egg	0.6	0.0	0.2	0.1	0.0	2.3	0.5	9.7	23.5	0.6
<i>Squilla</i>	—	—	—	—	—	0.4	0.2	0.1	0.1	0.0
<i>Lingula</i> sp.	0.9	1.0	2.0	2.7	0.1	1.4	0.7	1.3	2.8	0.1
Nematode	0.3	0.0	0.1	0.0	0.0	1.4	0.0	0.5	0.7	0.0
Algae	5.3	0.2	3.3	18.6	0.5	3.2	0.2	2.9	9.9	0.2
<i>Lucifer</i>	0.9	0.4	0.2	0.5	0.0	—	—	—	—	—
Coelenterate	0.9	0.7	0.9	1.4	0.0	—	—	—	—	—
<i>Coscinodiscus</i>	—	—	—	—	—	0.4	0.0	0.1	0.0	0.0
Tape worm	0.3	0.2	0.1	0.1	0.0	—	—	—	—	—

**Table 12**

Percent frequency of occurrence (%F), percent of total number (%N), percent of total volume (%V), and index of relative importance (IRI) for food items of male and female *Cynoglossus lida* caught off Porto Novo, India, October 1981–September 1982. Size group: 158–178 mm TL (*n* 284 ♂, *n* 260 ♀). See Table 10 for abbreviations.

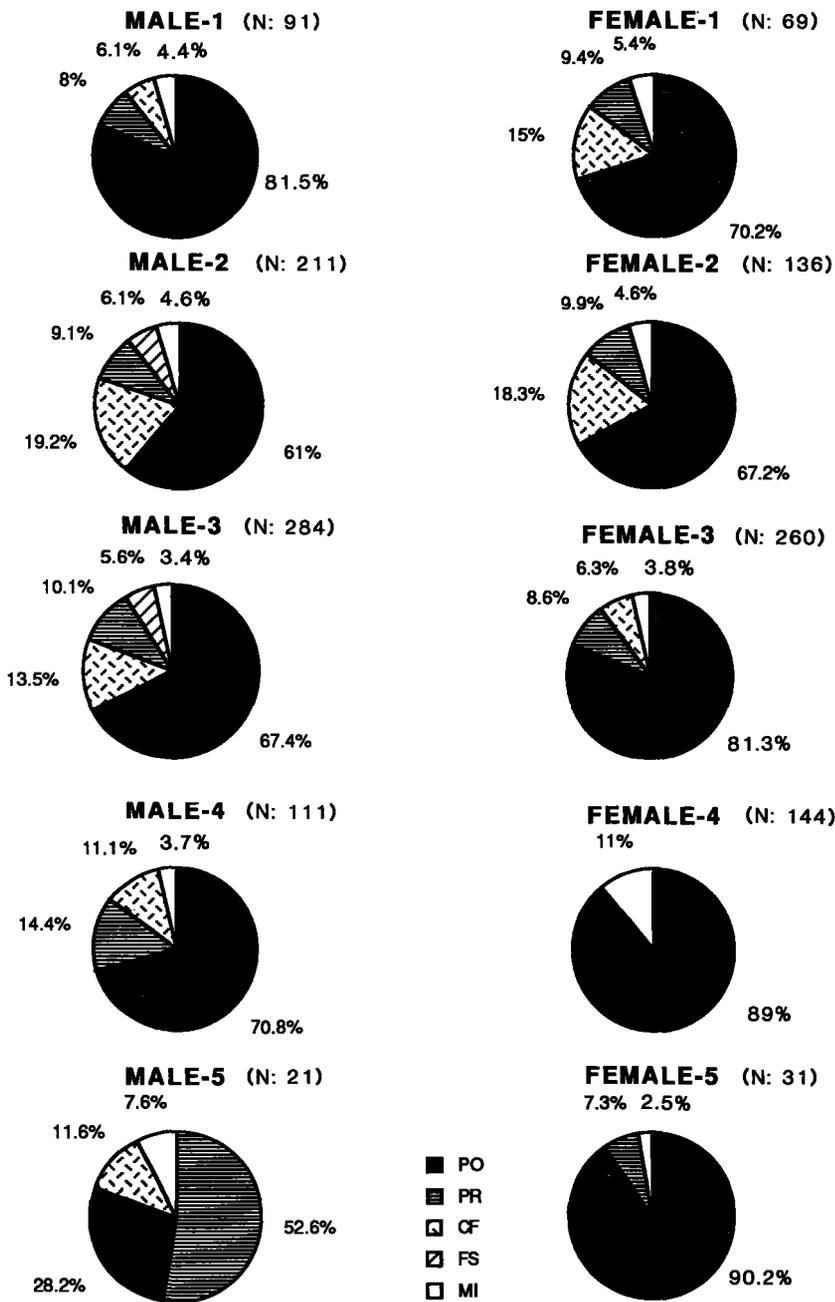
Food items	Male ( <i>n</i> 284)					Female ( <i>n</i> 260)				
	%F	%V	%N	IRI	%IRI	%F	%V	%N	IRI	%IRI
Polychaetes	29.0	61.2	28.4	2598.4	67.4	32.2	75.9	47.4	3970.3	81.3
Crustacean fr.	11.2	16.2	30.1	518.6	13.5	10.7	8.2	20.4	306.0	6.3
Prawns	16.2	14.9	9.2	390.4	10.1	18.3	12.5	10.4	419.1	8.6
Fish scales	14.9	1.4	12.7	210.1	5.6	8.9	0.4	4.4	42.7	0.8
Amphipods	9.7	0.8	7.1	76.6	2.0	14.7	0.6	8.1	127.9	2.6
Bivalves	0.5	0.4	0.4	0.4	0.0	2.5	0.7	0.9	4.0	0.1
Gastropods	2.6	0.2	1.2	3.6	0.1	1.4	0.1	0.5	0.8	0.0
Isopods	—	—	—	—	—	0.5	0.1	0.1	0.1	0.0
Copepods	0.8	0.0	0.2	0.2	0.0	0.8	0.0	0.3	0.2	0.0
Crabs	1.3	0.6	0.4	1.3	0.0	1.3	0.3	0.3	0.8	0.0
Fish spine	0.3	0.0	0.2	0.1	0.0	—	—	—	—	—
Fish egg	1.3	0.0	0.5	0.7	0.0	1.4	0.1	3.1	4.5	0.1
<i>Squilla</i>	0.5	0.5	0.2	0.4	0.0	1.0	0.4	0.3	0.7	0.0
<i>Lingula</i> sp.	0.5	0.1	0.2	0.2	0.0	0.8	0.4	1.0	1.1	0.0
Nematode	0.8	0.0	0.2	0.2	0.0	1.0	0.0	0.5	0.5	0.0
Algae	7.2	0.3	4.7	36.0	0.9	3.6	0.1	2.0	7.6	0.2
Egg mass (UI)	0.3	0.1	0.1	0.1	0.0	0.3	0.1	0.1	0.1	0.0
Coelenterate	2.1	3.2	3.9	14.9	0.4	0.3	0.1	0.1	0.1	0.0
<i>Coscinodiscus</i>	0.5	0.0	0.2	0.1	0.0	0.3	0.0	0.1	0.0	0.0
<i>Octopus</i> sp.	0.3	0.1	0.1	0.1	0.0	—	—	—	—	—

**Table 13**

Percent frequency of occurrence (%F), percent of total number (%N), percent of total volume (%V), and index of relative importance (IRI) for food items of male and female *Cynoglossus lida* caught off Porto Novo, India, October 1981–September 1982. Size group: 179–199 mm TL (*n* 111 ♂, *n* 144 ♀). See Table 10 for abbreviations.

Food items	Male ( <i>n</i> 111)					Female ( <i>n</i> 144)				
	%F	%V	%N	IRI	%IRI	%F	%V	%N	IRI	%IRI
Polychaetes	31.8	60.0	33.7	2979.7	70.8	35.7	82.4	56.5	4958.7	89.0
Prawns	20.6	16.9	12.6	607.7	14.4	14.9	9.1	8.3	259.3	4.7
Crustacean fr.	11.2	12.8	28.8	465.9	11.1	10.0	5.4	14.9	203.0	3.6
Fish scales	10.6	0.5	6.0	68.9	1.6	10.0	0.3	3.5	38.0	0.7
Amphipods	10.0	0.4	4.7	51.0	1.2	13.1	0.5	6.6	93.0	1.7
Bivalves	1.2	0.4	0.5	1.1	0.2	2.3	0.5	0.6	2.5	0.0
Gastropods	0.6	0.0	0.2	0.1	0.0	1.4	0.2	1.5	2.4	0.0
Isopods	1.2	0.3	0.3	0.7	0.0	3.2	0.5	0.7	3.8	0.1
Copepods	1.2	0.0	0.3	0.4	0.0	0.4	0.0	0.1	0.0	0.0
Crabs	1.2	0.4	0.3	0.8	0.0	1.4	0.3	0.3	0.8	0.0
Fish	0.5	1.8	0.2	1.0	0.0	—	—	—	—	—
Fish spine	—	—	—	—	—	0.4	0.0	0.2	0.1	0.0
Fish egg	1.8	0.0	0.5	0.9	0.0	2.3	0.1	2.8	6.7	0.1
<i>Lingula</i> sp.	—	—	—	—	—	0.4	0.6	1.8	1.0	0.0
Nematode	1.2	0.0	0.3	0.4	0.0	0.9	0.0	0.2	0.2	0.0
Algae	4.7	0.1	2.8	13.6	0.3	2.7	0.1	1.6	4.6	0.1
<i>Lucifer</i>	0.5	0.4	0.3	0.4	0.0	—	—	—	—	—
Coelenterate	1.2	6.0	8.3	17.2	0.4	—	—	—	—	—
<i>Coscinodiscus</i>	0.5	0.0	0.2	0.1	0.0	0.9	0.0	0.4	0.4	0.0

### CYNOGLOSSUS LIDA



**Figure 4**

Percentage contribution of food items to the diet of various size groups of male and female *Cynoglossus lida* caught commercially off Porto Novo, India, October 1981–September 1982. Male-1 (n 91) and Female-1 (n 69) = size group 95–136mm TL; Male-2 (n 211) and Female-2 (n 136) = 137–157mm TL; Male-3 (n 284) and Female-3 (n 260) = 158–178mm TL; Male-4 (n 111) and Female-4 (n 144) = 179–199mm TL; and Male-5 (n 21) and Female-5 (n 31) = 200–262mm TL. Only values >5% IRI are individually shown; values <5% IRI are clumped together into a single category, the unshaded wedge of the pie chart. PO = polychaetes, PR = prawns, CF = crustacean fragments, FS = fish scales, MI = miscellaneous.

male and female *C. arel* is shown in Figure 5. All other food items occurred sporadically (Tables 1–2).

In male *C. lida*, polychaetes were the dominant prey for 9 months (Table 3). In the remaining months, crustacean fragments (January and December) and prawns (May) dominated. In females, polychaetes were the primary food item for every month, except in January and December when crustacean fragments were the most important prey item (Table 4).

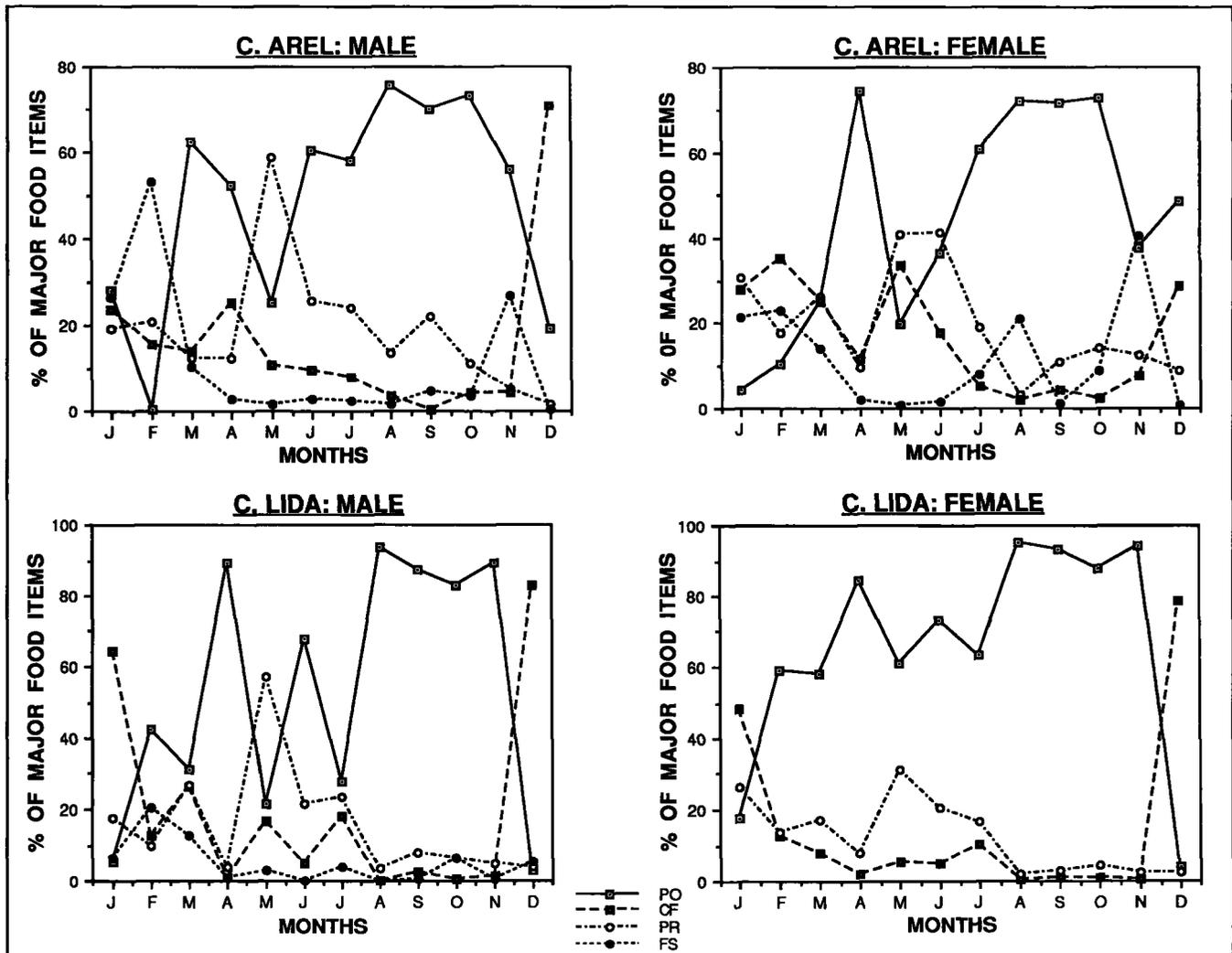
Prawns were next in importance in both sexes of *C. lida*. In males, prawns formed the secondary prey item except in February, May, July, October, and December. During these 5 months, fish remains (February, October, and December), polychaetes (May), and amphipods (July) were the secondary prey. In females, prawns were the secondary food, except in August and October–December. During these 4 months, amphipods (August and November), fish remains (October), and fish eggs (December) were consumed by females. The tertiary food group in the diet of male and female *C. lida* is shown in Figure 5. Organisms of lesser importance are listed in Tables 3–4.

**Gastro- (GI) and hepatosomatic (HI) indices and occurrence of empty stomachs in relation to spawning** In male *C. arel*, a peak occurrence of empty stomachs (Fig. 6) occurred in January, which is the peak spawning period. Lowest gastro- and hepatosomatic indices were also observed in January (Fig. 6). However, over the rest of the year, these factors did not appear to be related. The gastro- and hepatosomatic indices did not track the percentage occurrence of empty stomachs throughout the year.

**Table 14**

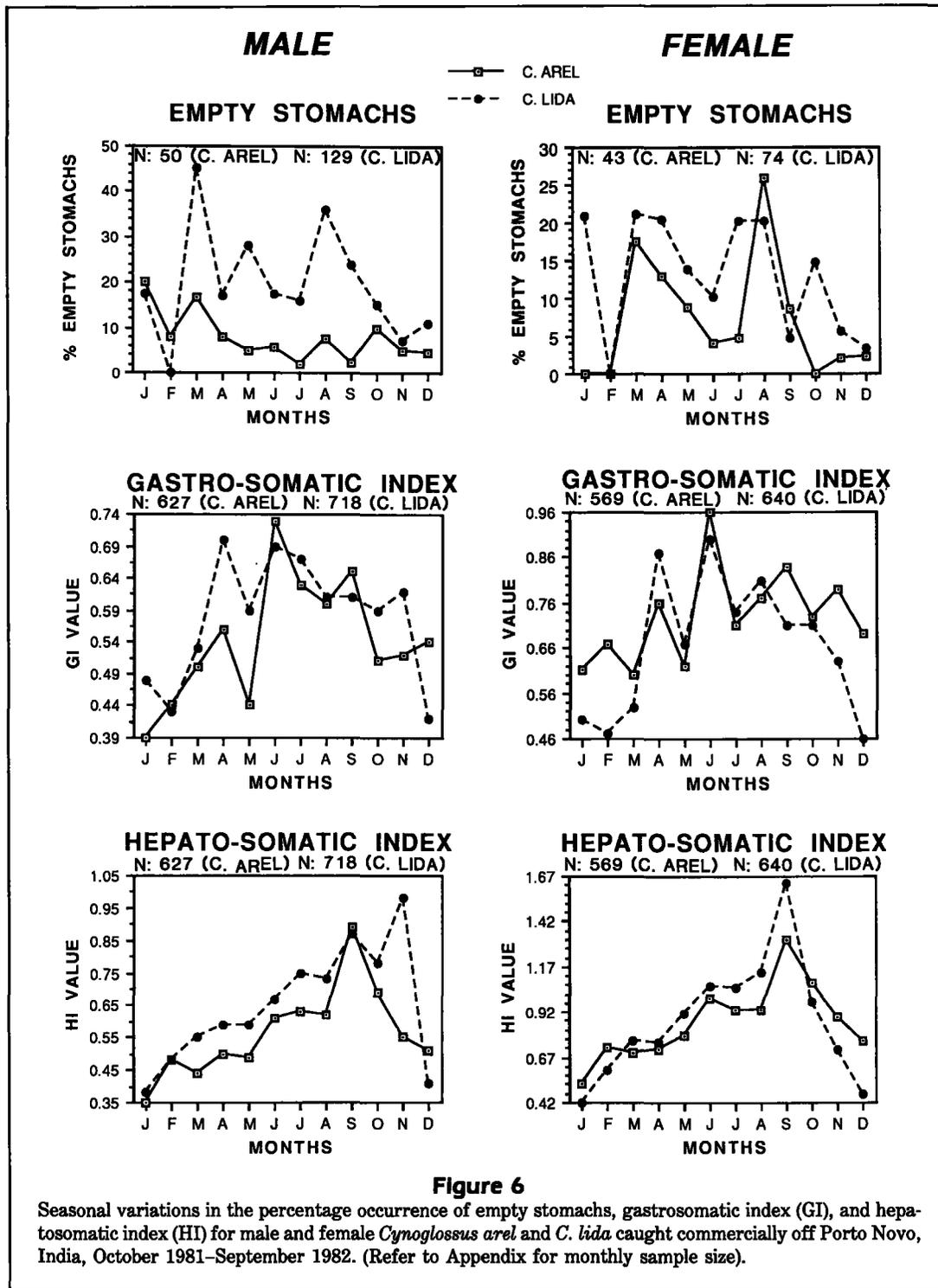
Percent frequency of occurrence (%F), percent of total number (%N), percent of total volume (%V), and index of relative importance (IRI) for food items of male and female *Cynoglossus lida* caught off Porto Novo, India, October 1981–September 1982. Size groups: 200–220 mm TL (n 19 ♂, n 27 ♀); 221–241 mm TL (n 1 ♂, n 3 ♀), and 242–262 mm TL (n 1 ♂, n 1 ♀) combined. See Table 10 for abbreviations.

Food items	Male (n 21)					Female (n 31)				
	%F	%V	%N	IRI	%IRI	%F	%V	%N	IRI	%IRI
Polychaetes	25.0	25.7	16.4	1052.5	28.2	39.1	84.8	70.8	6084.0	90.2
Prawns	25.0	42.5	36.1	1965.0	52.6	21.7	10.7	11.9	490.4	7.3
Crustacean fr.	10.0	12.2	31.1	433.0	11.6	10.9	1.8	6.2	87.2	1.3
Fish scales	10.0	0.3	3.4	37.0	1.0	8.7	0.1	2.3	20.9	0.3
Amphipods	15.0	0.6	8.2	132.0	3.4	8.7	0.3	4.2	39.2	0.5
Bivalves	—	—	—	—	—	4.3	2.1	3.4	23.7	0.4
Isopods	5.0	1.3	1.6	14.5	0.4	—	—	—	—	—
Copepods	—	—	—	—	—	2.2	0.0	0.4	0.9	0.0
Crabs	5.0	2.0	1.6	18.0	0.5	—	—	—	—	—
Fish	5.0	15.4	1.6	85.0	2.3	—	—	—	—	—
<i>Lingula</i> sp.	—	—	—	—	—	2.2	0.2	0.4	1.3	0.0
Nematode	—	—	—	—	—	2.2	0.0	0.4	0.9	0.0



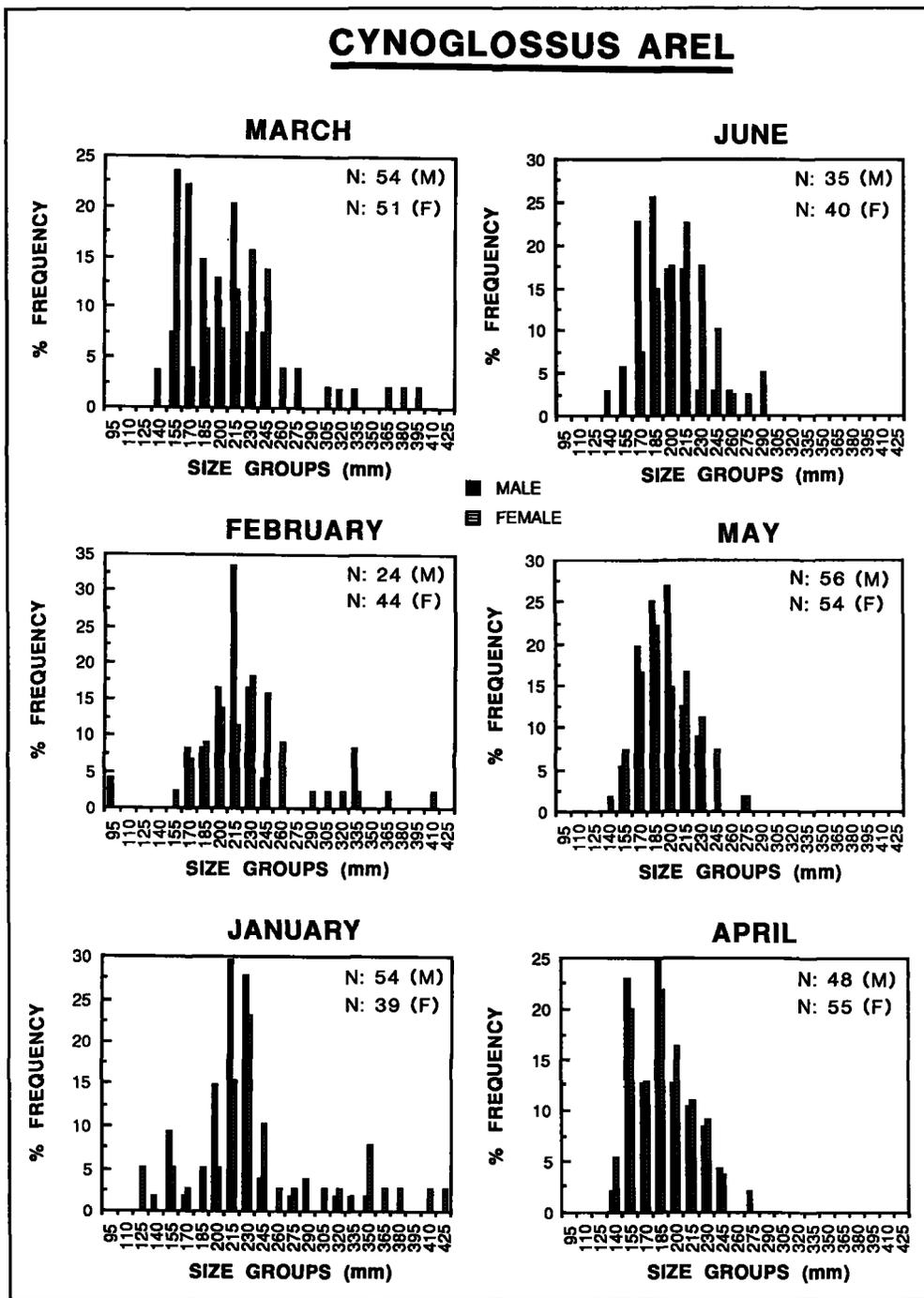
**Figure 5**

Seasonal variations in percentage contribution of major food items to the diet of male and female *Cynoglossus arel* and *C. lida* caught commercially off Porto Novo, India, October 1981–September 1982. Only values >5% IRI value are graphed. (Refer to Appendix for monthly sample size). PO = polychaetes, CF = crustacean fragments, PR = prawns, FS = fish scales.



In female *C. arel*, occurrence of empty stomachs did not correspond with spawning. However, the lowest values of gastro- and hepato-somatic indices were recorded (Fig. 6) only during the peak spawning period (in January).

In both sexes of *C. lida*, gastro-/hepatosomatic indices and the occurrence of empty stomachs did not reveal any relationship (Fig. 6) with peak spawning activities (in September) of this species.



**Figure 7A**  
Size-frequency histograms for male (M) and female (F) *Cynoglossus arel* (January–June) caught commercially off Porto Novo, India, October 1981–September 1982.

**Age and growth**

**Petersen method** Progression of modes in the length-frequency data could be traced for both sexes of *C. arel* and *C. lida* (Figs. 7, 8).

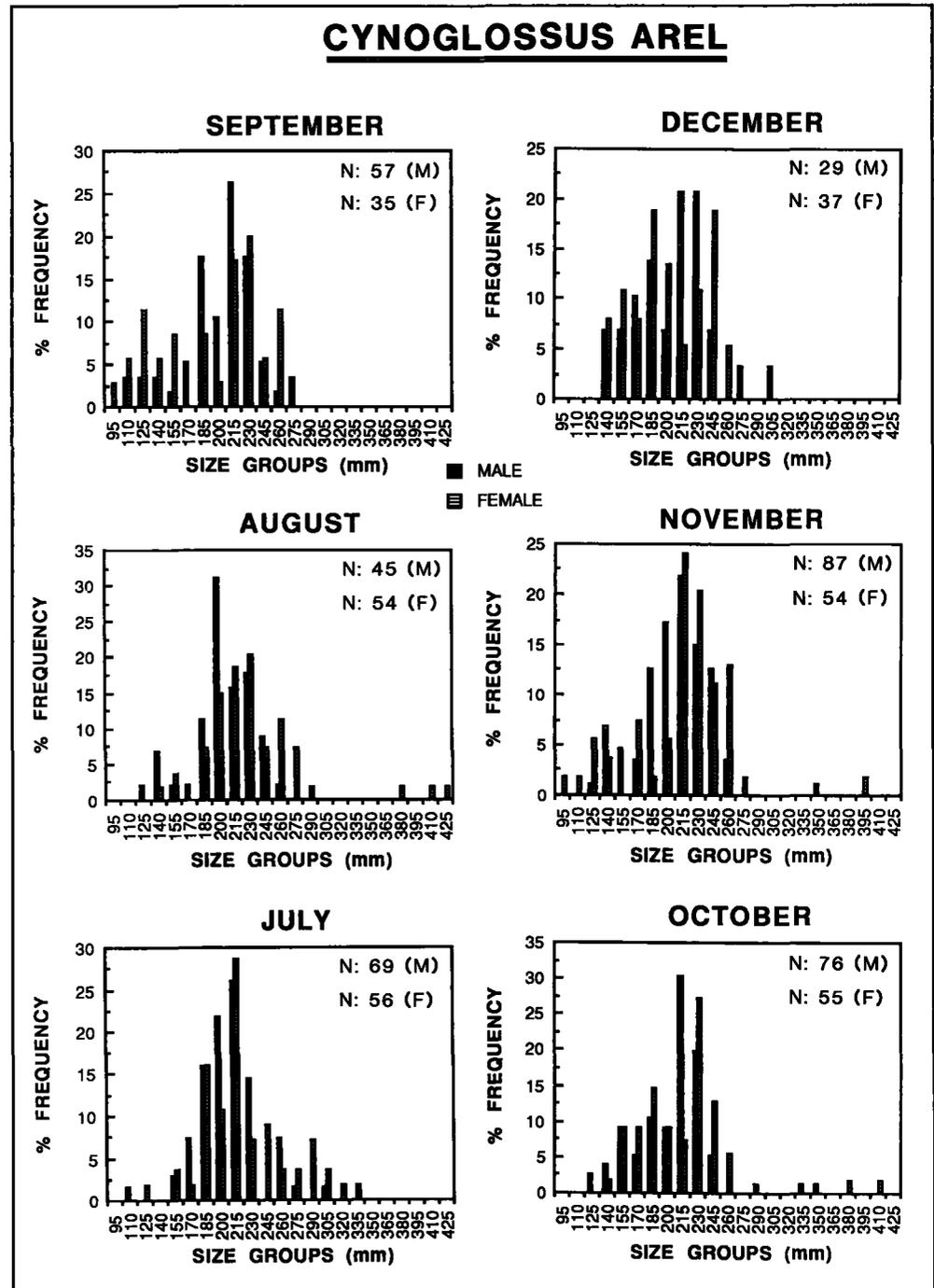
In male *C. arel* (Fig. 7), the first mode was the 155–169 mm length-group in January. A progressive shift during subsequent months until October, to the 290–304 mm length-group, indicated a growth of 135 mm in 9 months. Assuming the same rate of growth,

a fish would attain a length of 180 mm in the first year. Beyond November, it was not possible to trace length-groups.

In female *C. arel* (Fig. 7), the first mode was the 125–139 mm length-group in September. A progressive shift during subsequent months until March, to the 230–240 mm length-group, indicated a growth of 105 mm in 6 months. Groups could not be traced beyond April. At the same rate of growth, a fish would have

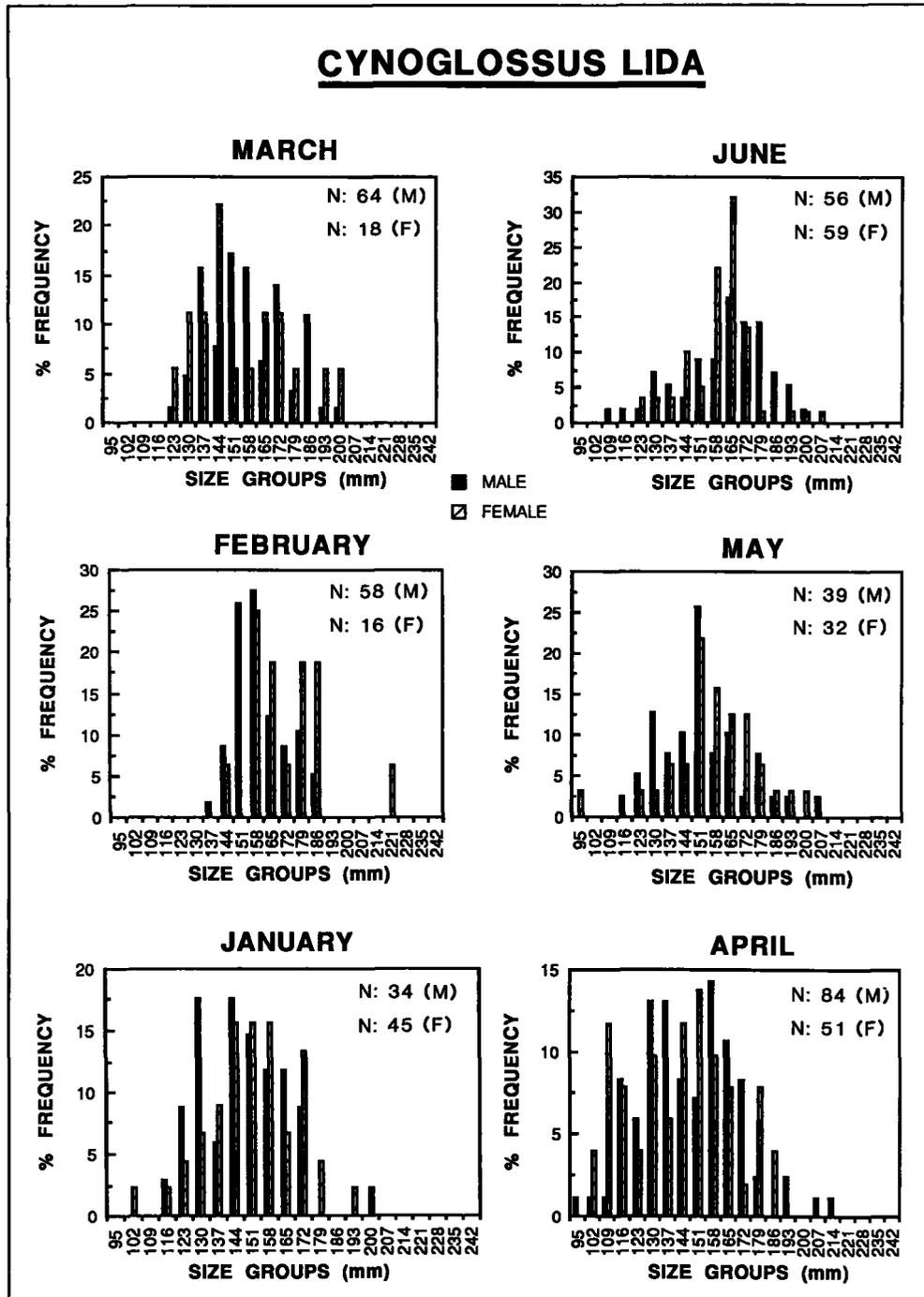
**Figure 7B**

Size-frequency histograms for male (M) and female (F) *Cynoglossus arel* (July–December) caught commercially off Porto Novo, India, October 1981–September 1982.



attained a length of 210 mm in the first year. There was another mode at the 200–214 mm length-group during February. A progressive shift of this mode during subsequent months until November, to the 260–274 mm length-group, indicated a growth of 60 mm in 9 months. Groups could not be traced beyond December. Based on this rate of growth, a fish would reach 290 mm at the end of the second year. Because of poorer representation in older size-groups, later modes were not traced.

In male *C. lida* (Fig. 8), the first mode was the 102–108 mm size-group in November. This was traced to the 179–185 mm size-group in May, 77 mm of growth in 6 months. Length-groups could not be traced beyond June. At this rate, a fish would be 154 mm at the end of the first year. The mode at the 151–157 mm size-group in March was traced to the 179–185 mm size-group in November, 28 mm growth in 8 months. At this rate of growth, a fish at the end of the second



**Figure 8A**  
Size-frequency histograms for male (M) and female (F) *Cynoglossus lida* (January–June) caught commercially off Porto Novo, India, October 1981–September 1982.

year would be 196mm. Further modes could not be traced.

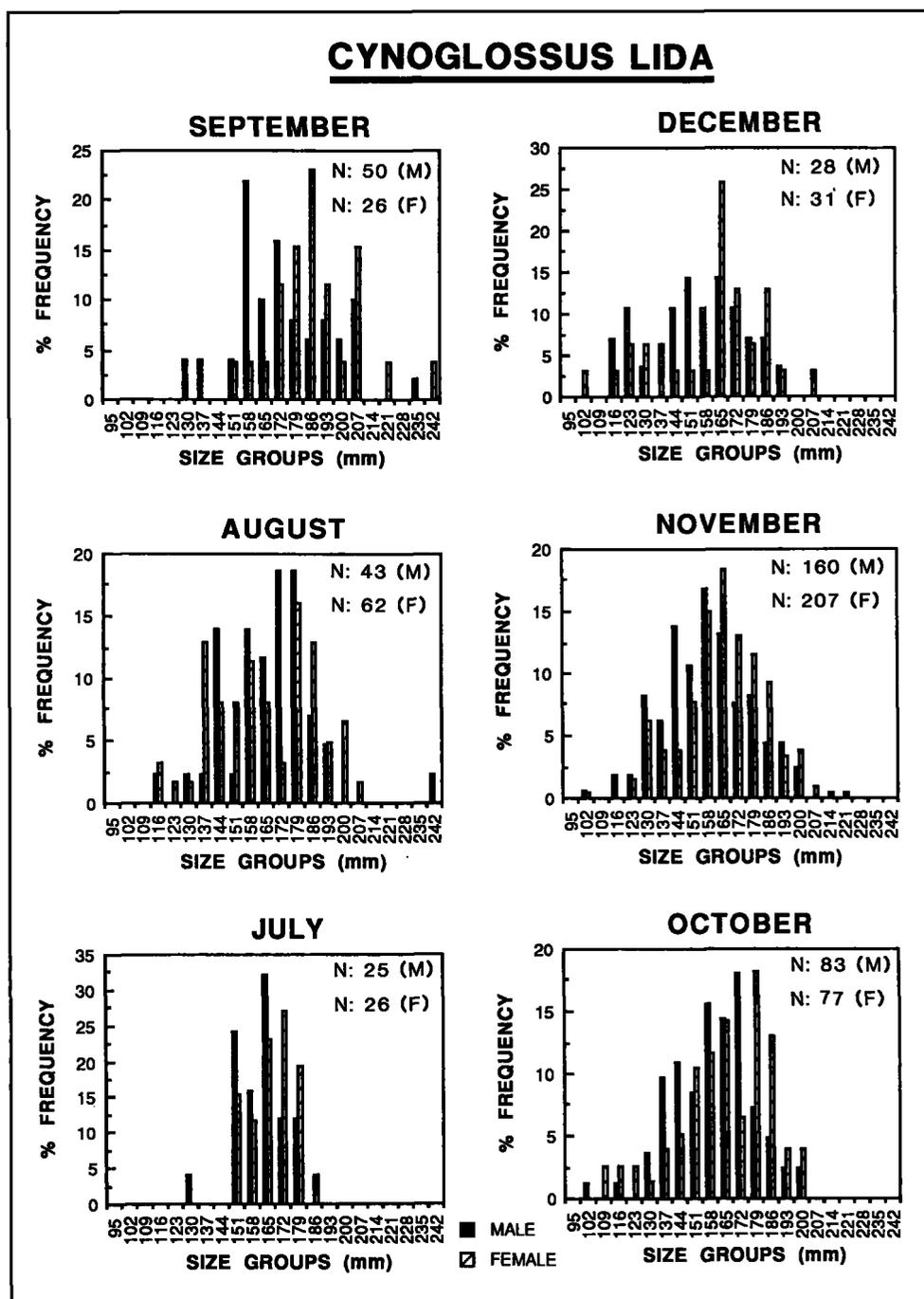
In female *C. lida* (Fig. 8), the first mode was the 102–108 mm size-group in November. This was traced to the 193–199 mm size-group in June, 91 mm growth in 7 months. At this rate, a fish would be 156 mm in the first year. The mode at the 151–157 mm size-group in January was traced back to the 193–199 mm size-group in January, 42 mm growth in 12 months. A fish

would be 198 mm at the end of the second year. The mode at the 193–199 mm size-group in May was traced to the 207–213 mm size-group in December, 14 mm growth in 7 months. At this rate, a fish at the end of the third year would be 222 mm.

The rate of growth from the time of hatching and throughout the first year would be more rapid than that of the older year-classes.

**Figure 8B**

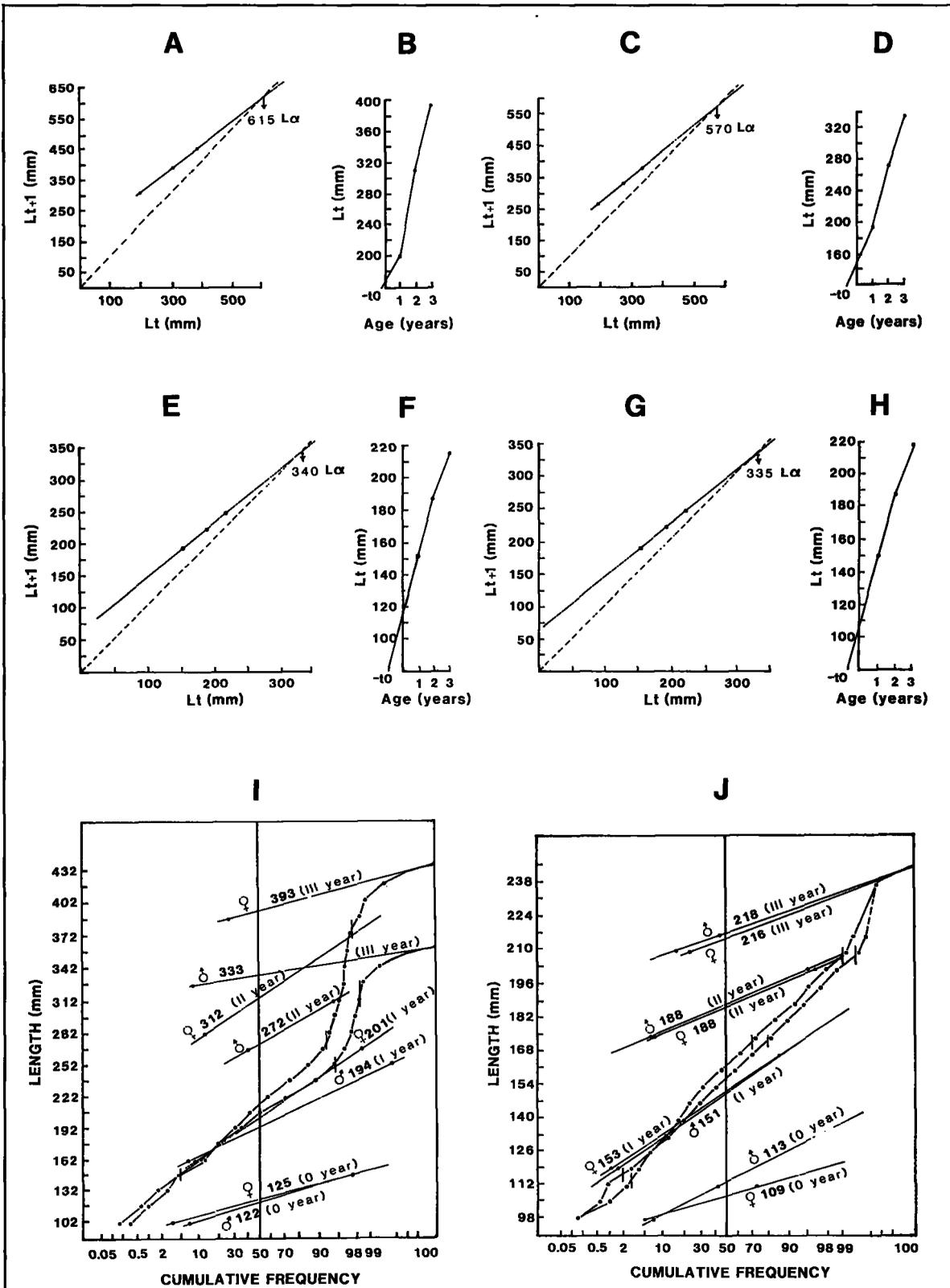
Size-frequency histograms for male (M) and female (F) *Cynoglossus lida* (July–December) caught commercially off Porto Novo, India, October 1981–September 1982.



**Probability plot method** Cumulative percentage distribution of lengths was calculated for *C. arel* and *C. lida*, and plotted against the midpoints of length-groups on probability paper (Fig. 9I, J). These points formed approximately straight lines, but slight deviations could be recognized. Based on the probability plots, male *C. arel* attained 194 mm, 272 mm, and 333 mm in the 1st, 2d, and 3d years, respectively, while females reached 201, 312, and 393 mm for these years.

In *C. lida*, males attained 151, 188, and 218 mm, while females reached 153, 188, and 216 mm, in the 1st, 2d, and 3d years, respectively.

**von Bertalanffy's equation** Plots of  $L_{t+1}$  against  $L_t$ , showing a straight-line relationship for *C. arel* and *C. lida*, were drawn. A least-square line was then fitted and an estimate of  $L_{\infty}$  was obtained (Fig. 9A, C, E, G). By this Ford-Walford graph,  $L_{\infty}$  was 570 mm for male



**Figure 9**

Age and growth of *Cynoglossus arel* and *C. lida* caught commercially off Porto Novo, India, October 1981–September 1982. Ford-Walford plot for female (A) and male (C) *C. arel*, and for female (E) and male (G) *C. lida*; theoretical growth curve for female (B) and male (D) *C. arel*, and female (F) and male (H) *C. lida*; probability plot for male and female *C. arel* (I) and *C. lida* (J).

and 615 mm for female *C. arel*; 335 mm for male and 340 mm for female *C. lida*.

Based on values obtained, the von Bertalanffy's equations are:

***C. arel***

Male  $L_t = 570(1 - e^{-0.2376(t+0.7753)})$

Female  $L_t = 615(1 - e^{-0.3151(t+0.2645)})$

***C. lida***

Male  $L_t = 335(1 - e^{-0.2326(t+1.6348)})$

Female  $L_t = 340(1 - e^{-0.2231(t+1.8029)})$

Male *C. arel* reached 194, 272, and 333 mm in the 1st, 2d, and 3d years, respectively (Fig. 9D), while females attained a length of 201, 312, and 393 mm for the 1st, 2d, and 3d years, respectively (Fig. 9B). Male *C. lida* reached 151, 188, and 218 mm (Fig. 9H), while females attained lengths of 153, 188, and 216 mm in the 1st, 2d, and 3d years, respectively (Fig. 9F).

Estimates of age and growth, based on the three different methods, are presented in Table 15.

**Length-weight relationships**

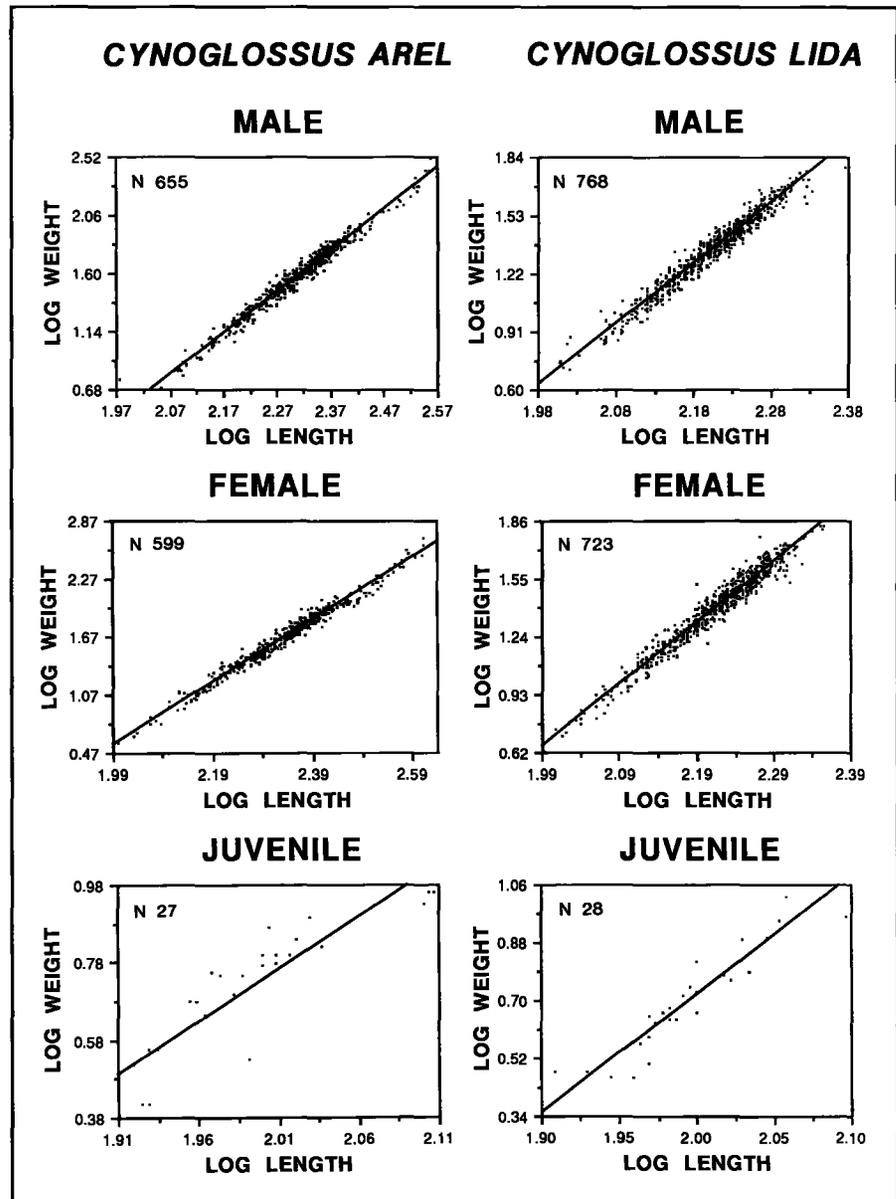
The linear relationships in logarithmic values of length and weight for males, females, and juveniles are shown in Figure 10A. These were typical length-weight relationships in which length increase is rapid initially, but later slows down with a corresponding increase in weight. Correlation coefficient values (*r*) are highly significant as follows:

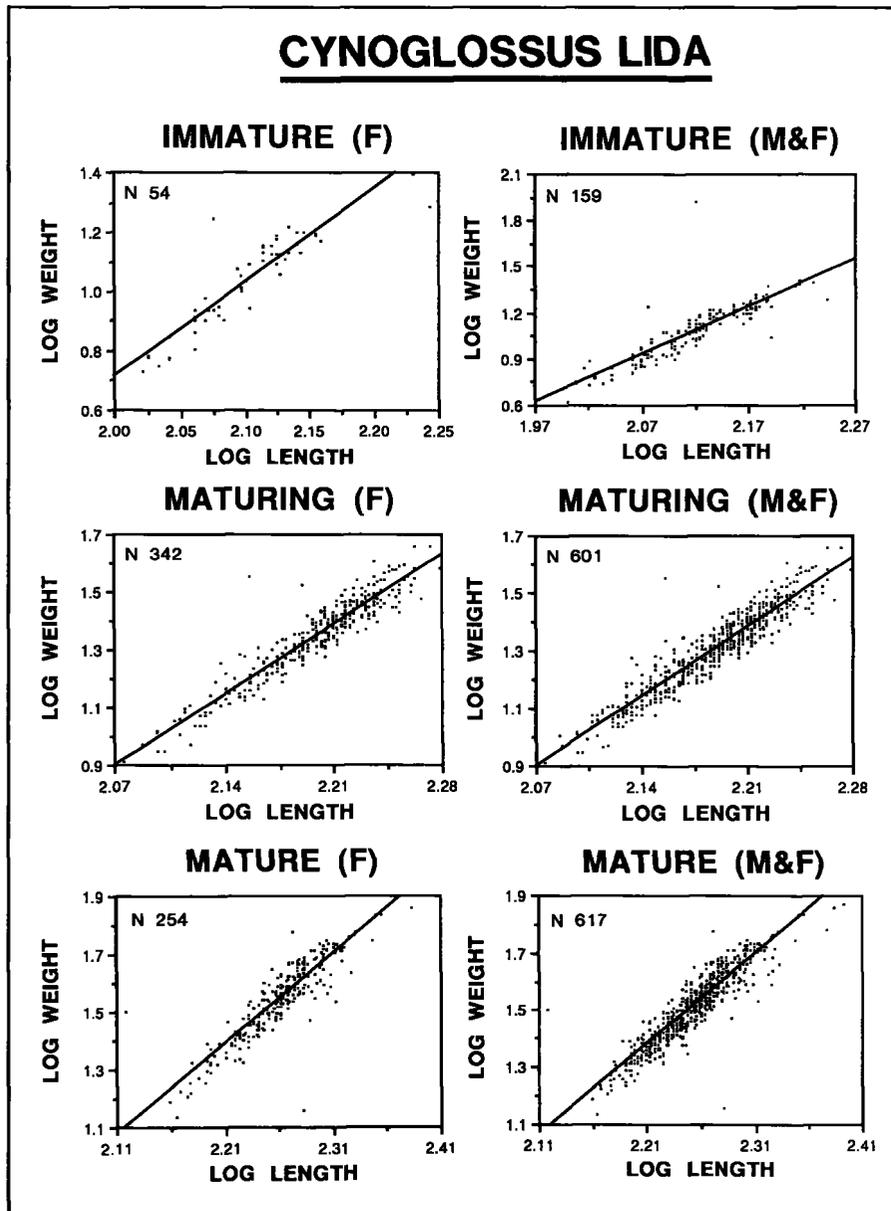
**Figure 10A**

Length-weight relationships for male, female, and juvenile *Cynoglossus arel* and *C. lida* caught commercially off Porto Novo, India, October 1981–September 1982.

**Table 15**  
Mean length (mm) attained in different years of life (per 3 methods) by *Cynoglossus arel* and *C. lida* caught commercially off Porto Novo, India, October 1981–September 1982.

Species	Year	Method			
		Petersen	Probability plot	von Bertalanffy	
<i>Cynoglossus arel</i>	Male	I	180	194	194
		II	—	272	272
		III	—	333	333
	Female	I	210	201	201
		II	290	312	312
		III	—	393	393
<i>Cynoglossus lida</i>	Male	I	154	151	151
		II	196	188	188
		III	—	218	218
	Female	I	156	153	153
		II	198	188	188
		III	222	216	216



**Figure 10B**

Length-weight relationships for immature, maturing, and mature females (F), and pooled sexes (M&F) of *Cynoglossus lida* caught commercially off Porto Novo, India, October 1981–September 1982.

differences noted for the remaining 8 months (Table 17). In *C. lida*, no significant differences were observed in regression coefficients of length and weight between males and females.

Analysis of covariance was employed to determine whether growth patterns differed significantly between stages of maturity (immature, maturing, and mature) in males and females. No significant differences were noted for *C. arel* ( $P > 0.05$ ). Hence immature, maturing, and mature male and female *C. arel* were combined irrespective of sexes. As there was no significant difference in the regression of Y and X between maturity stages irrespective of sexes, the data for male, female, and juvenile *C. arel* were pooled for the entire year, irrespective of months and maturity stages, and the linear equation was fitted for males, females, and juveniles. Analysis of covariance was again employed for the pooled data to test whether growth patterns differed significantly between sexes of *C. arel*. Significant differences

*C. arel* Male 0.9870 ( $P < 0.001$ )  
 Female 0.9905 ( $P < 0.001$ )  
 Juvenile 0.8747 ( $P < 0.001$ )

*C. lida* Male 0.9782 ( $P < 0.001$ )  
 Female 0.9756 ( $P < 0.001$ )  
 Juvenile 0.9409 ( $P < 0.001$ ).

Calculated b, a, r values, and observed *F* values are presented in Tables 16 and 17.

Linear equations were computed separately for males and females of each month to examine variations in growth patterns. In *C. arel*, significant differences were observed in regression coefficients during January, February, May, and July, with no significant

were obtained in the b value between male, female, and juvenile *C. arel*. On comparing males and females, males and juveniles, and females and juveniles, significant values were obtained. Since the growth rates of males, females, and juveniles differed significantly from one another, three separate equations, relating logW to logL, are presented for *C. arel* as follows,

*C. arel* Male  $\log W = -5.9551 + 3.2665 \log L$   
 Female  $\log W = -5.8231 + 3.2100 \log L$   
 Juvenile  $\log W = -4.8615 + 2.7901 \log L$ ,

and the parabolic equations are

Male  $W = 0.0000011 L^{3.2665}$   
 Female  $W = 0.0000015 L^{3.2100}$   
 Juvenile  $W = 0.0000138 L^{2.7901}$ .

**Table 16**

Results of linear regressions of length-weight relations in *Cymoglossus arel* and *C. lida* caught off Porto Novo, India, October 1981–September 1982.  $r^*$  = all  $r$  values were significant at 0.1% level.

Sample	<i>Cymoglossus arel</i>				<i>Cymoglossus lida</i>			
	<i>N</i>	$r^*$	<i>a</i>	<i>b</i>	<i>N</i>	$r^*$	<i>a</i>	<i>b</i>
<b>By months</b>								
<b>Male</b>								
January	52	0.9920	-5.6785	3.1411	24	0.9900	-6.4285	3.5199
February	34	0.9902	-4.9278	2.8233	48	0.9872	-5.8703	3.2715
March	51	0.9785	-5.7827	3.1860	85	0.9822	-6.4397	3.5300
April	46	0.9834	-5.5809	3.0970	86	0.9878	-5.4470	3.0715
May	57	0.9813	-6.3448	3.4326	62	0.9823	-5.6679	3.1747
June	44	0.9887	-6.3781	3.4432	54	0.9705	-5.6760	3.1793
July	70	0.9868	-5.8109	3.1991	37	0.9677	-6.0573	3.3573
August	54	0.9951	-6.0999	3.3202	45	0.9860	-5.6693	3.1758
September	59	0.9913	-5.9119	3.2575	62	0.9809	-5.2038	2.9803
October	81	0.9907	-6.1854	3.3770	83	0.9678	-5.5118	3.1283
November	70	0.9922	-6.1151	3.3468	135	0.9823	-5.4126	3.0827
December	37	0.9930	-6.0433	3.3060	47	0.9879	-5.7740	3.2354
Total	655	0.9870	-5.9551	3.2665	768	0.9782	-5.7717	3.2315
<b>Female</b>								
January	49	0.9959	-5.9501	3.2687	31	0.9899	-6.1744	3.4089
February	52	0.9913	-5.6840	3.1432	45	0.9935	-5.8431	3.2598
March	47	0.9926	-5.7543	3.1782	38	0.9866	-6.1015	3.3718
April	58	0.9825	-5.3251	2.9920	54	0.9893	-5.6817	3.1849
May	52	0.9812	-5.6617	3.1412	43	0.9703	-5.7400	3.2157
June	41	0.9831	-6.0536	3.3047	54	0.9624	-5.1232	2.9342
July	55	0.9807	-5.0773	2.8787	44	0.9601	-5.9178	3.2983
August	66	0.9969	-6.2004	3.3643	64	0.9886	-5.6065	3.1489
September	39	0.9955	-5.8507	3.2361	37	0.9533	-5.2175	2.9923
October	57	0.9928	-5.9232	3.2654	80	0.9739	-5.7639	3.2454
November	45	0.9870	-5.8994	3.2511	168	0.9680	-5.7278	3.2335
December	38	0.9921	-6.0110	3.2960	65	0.9898	-5.9707	3.3277
Total	599	0.9905	-5.8231	3.2100	723	0.9756	-5.9084	3.2987
<b>Juvenile</b>								
All months	27	0.8747	-4.8615	2.7901	28	0.9409	-6.5983	3.6579
<b>By maturity stages</b>								
<b>Male</b>								
Immature	56	0.9524	-4.7589	2.7205	105	0.8264	-5.5077	3.1101
Maturing	221	0.8111	-5.4998	3.0714	259	0.9260	-5.8584	3.2713
Mature	359	0.8909	-5.4090	3.0404	363	0.9328	-5.5189	3.1182
<b>Female</b>								
Immature	47	0.9266	-4.5468	2.6221	54	0.8867	-5.0851	2.9124
Maturing	224	0.9463	-4.8001	2.7575	342	0.9392	-6.2651	3.4629
Mature	292	0.9104	-4.9627	2.8516	254	0.8054	-5.5588	3.1443
<b>Male and female</b>								
Immature	103	0.9391	-4.6496	2.6699	159	0.8542	-5.3162	3.0209
Maturing	445	0.8725	-5.0463	2.8687	601	0.9399	-6.2280	3.4439
Mature	651	0.9089	-5.1071	2.9122	617	0.8726	-5.6599	3.1843

In *C. lida*, the tests made to check the relationship between length and weight during various stages of maturity (immature, maturing, and mature) in males and females showed significant differences between the three maturity stages in females alone and in pooled sexes, whereas males showed no significant differ-

ences. Hence logarithmic equations for immature, maturing, and mature females, as well as pooled sexes of *C. lida*, are presented as follows,

**C. lida****Female alone**

$$\text{Immature } \log W = -5.0851 + 2.9124 \log L$$

$$\text{Maturing } \log W = -6.2651 + 3.4629 \log L$$

$$\text{Mature } \log W = -5.5588 + 3.1443 \log L$$

**Pooled sexes**

$$\text{Immature } \log W = -5.3162 + 3.0209 \log L$$

$$\text{Maturing } \log W = -6.2280 + 3.4439 \log L$$

$$\text{Mature } \log W = -5.6599 + 3.1843 \log L$$

The linear relationships in logarithmic values of length and weight for immature, maturing, and mature female, as well as pooled sexes of *C. lida*, are shown in Figure 10B.

Although female maturity exhibited a significant effect on the length-weight relationship, all data for male, female, and juvenile *C. lida* were treated separately, irrespective of month and maturity stage. Analysis of covariance was used to find variations in the growth patterns of males, females, and juveniles. Significant differences were observed in regression coefficients of males, females, and juveniles. While comparing males and juveniles, a significant difference was noted; however, no significant differences were observed in comparing males and females, and females and juveniles. Hence two logarithmic equations, one common equation for adults (male and female) and another

for juveniles, are presented for *C. lida* as follows,

**C. lida**

$$\text{Male \& female } \log W = -5.8643 + 3.2761 \log L$$

$$\text{Juveniles } \log W = -6.5983 + 3.6579 \log L,$$

and the parabolic equations are

**Table 17**

Observed F values and their significance in length-weight relationships of *Cynoglossus arel* and *C. lida* caught commercially off Porto Novo, India, October 1981–September 1982. \* $P < 0.05$ .

Samples	<i>C. arel</i>	<i>C. lida</i>
<b>Comparison between male, female, and juvenile</b>		
January Male × Female	8.0000*	1.8571
February Male × Female	12.2941*	0.0000
March Male × Female	0.0000	1.6923
April Male × Female	1.1667	1.8182
May Male × Female	5.5000*	12.0000
June Male × Female	1.1429	2.1765
July Male × Female	10.1667*	0.0000
August Male × Female	1.8333	9.0000
September Male × Female	8.0000	0.0000
October Male × Female	2.3125	1.1875
November Male × Female	1.0625	3.1333
December Male × Female	0.0000	1.1250
<b>All months</b>		
Male × Female × Juvenile	4.8571*	3.7368*
Male × Female	4.2500*	3.3889
Male × Juvenile	6.8000*	5.5882*
Female × Juvenile	4.6522*	3.1905
<b>Comparison between maturity stages</b>		
<b>Male</b>		
Immature × Maturing × Mature	1.5915	1.2727
Immature × Maturing	2.1798	1.3333
Immature × Mature	3.5556	0.0000
Maturing × Mature	24.6667	2.1176
<b>Female</b>		
Immature × Maturing × Mature	1.0303	4.3913*
Immature × Maturing	1.0625	11.6296*
Immature × Mature	1.2826	1.4038
Maturing × Mature	1.6098	4.6000
<b>Male and female combined</b>		
Immature × Maturing × Mature	1.7971	7.2162*
Immature × Maturing	2.2131	13.6765*
Immature × Mature	3.4789	1.4000
Maturing × Mature	5.0714	8.6452*

$$\begin{aligned} \text{Male and female } W &= 0.0000014 L^{3.2761} \\ \text{Juvenile } W &= 0.0000003 L^{3.6579} \end{aligned}$$

The *t*-test was employed, and the calculated *b* value was found to differ significantly from the hypothetical *B* value (=3), at 5% level, in male and female *C. arel* and in adult and juvenile *C. lida*, whereas juvenile *C. arel* showed no significant difference:

$$\begin{aligned} \text{C. arel Male } t &= 12.8125 \\ \text{Female } t &= 11.5385 \\ \text{Juvenile } t &= -0.6788 \end{aligned}$$

$$\begin{aligned} \text{C. lida Male \& female } t &= 14.8441 \\ \text{Juvenile } t &= 2.5470 \end{aligned}$$

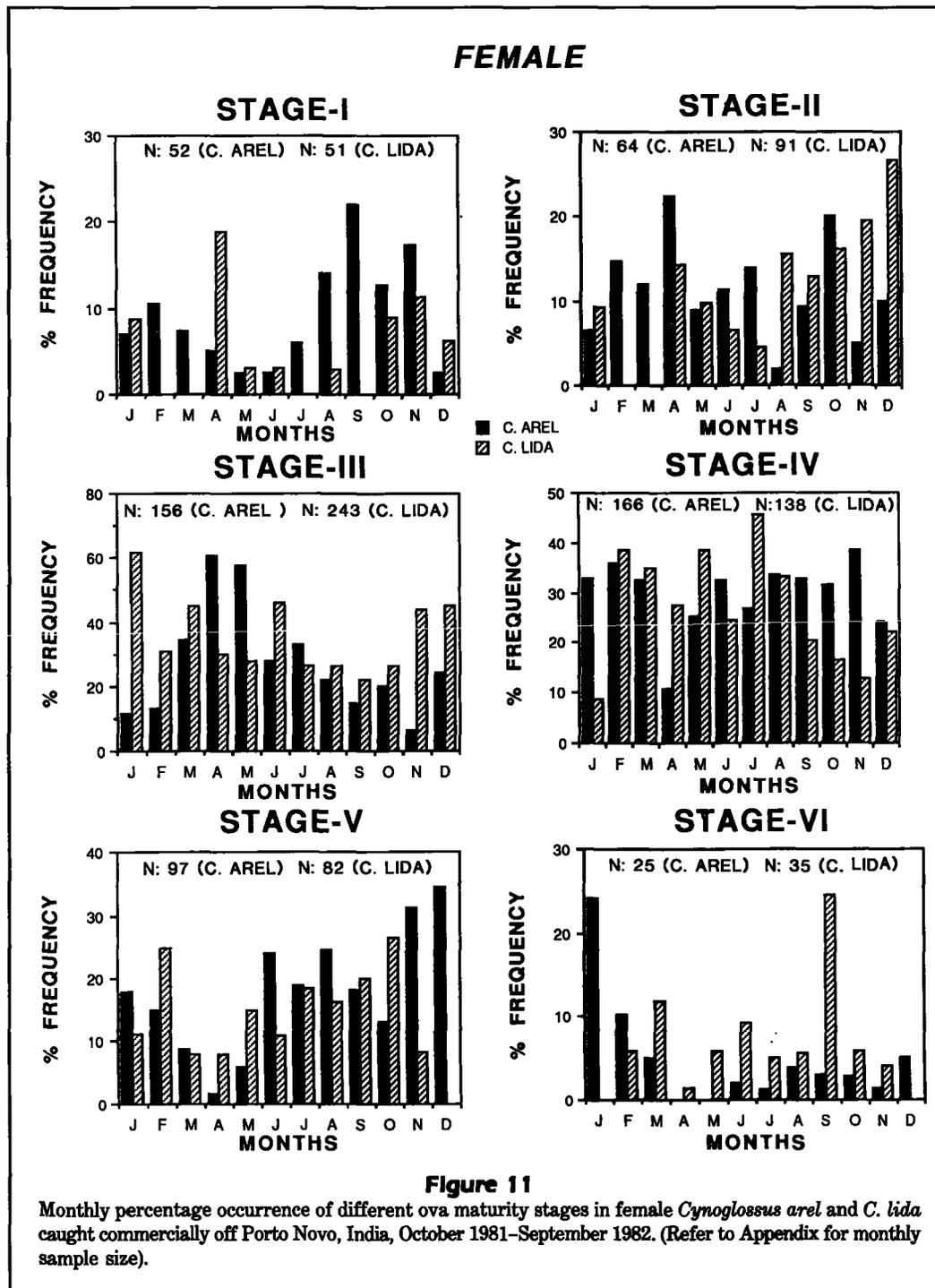
Hence it is clear that the cubic formula is not a proper representation of length-weight relationship in male and female *C. arel* and in adult and juvenile *C. lida*.

## Reproductive biology

**Seasonal occurrence of maturity stages** Female *C. arel* with Stage-I ovaries occurred throughout the year, with a peak in September (Fig. 11). Stage-II ovaries were also present during all months, with higher percentages in April and October. Individuals with Stage-III ovaries occurred throughout the year, with higher proportions during March–May and July. Specimens with Stage-IV (mature ovaries) were present throughout the year, with a peak in November. Stage-V (ripe ovaries) were also noted during all months of the year, but maximum abundance was observed in November and December. Specimens with Stage-VI (oozing ovaries) were collected in all months except April and May. High incidence of oozing ovaries was observed in January and February. This indicates that the spawning occurs for up to 10 months (June–March). Occurrence of Stage-VI specimens, with a peak in January, indicates that the maximum number of individuals may spawn during January, which is the post-(northeast) monsoon period in Porto Novo.

In male *C. arel* (Fig. 12), immature (Stage-I), maturing (Stage-II), and mature (Stage-III) individuals occurred throughout the year. High percentages of individuals with Stage-I testes occurred in March and October–December. Maturing specimens (Stage II) were abundant from February to September. Occurrence of mature males (Stage III) showed a peak in January. Occurrence of a higher percentage of fully-mature specimens in January indicated that even though the spawning probably occurred year-round, the majority of individuals might spawn during the post-(northeast) monsoon period (January) in Porto Novo.

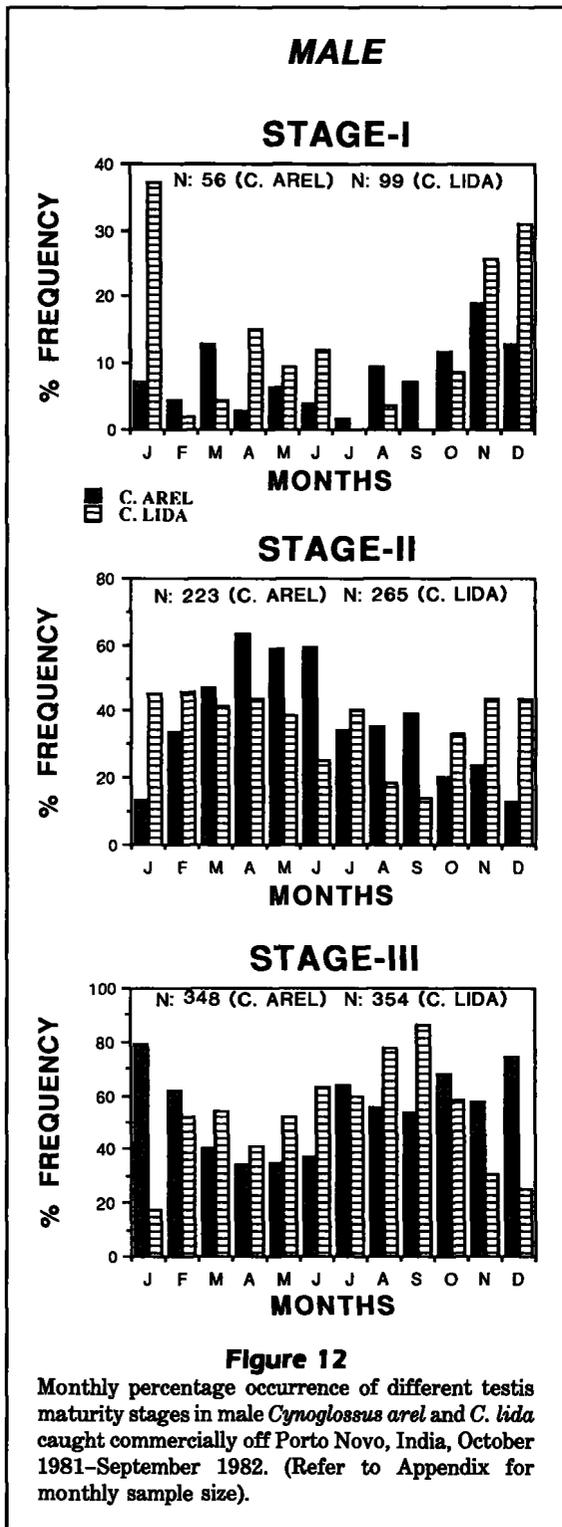
Female *C. lida* (Fig. 11) with Stage-I (immature) ovaries occurred for 9 months (absent in February, March, and July), with a peak in April. Stage-II (virgin maturing) individuals were present during all months except February and March, with a peak in December. Stage-III (maturing) ovaries were present throughout the year, with abundance in January, March, June, November, and December. Stage-IV (mature) specimens were present during all months of the year, with higher proportions during February, March, May, and July. Stage-V (ripe) individuals occurred throughout the year, except in December, with maximum abundance in February and September–October. Specimens with Stage-VI (oozing) ovaries were noted for 10 months (absent in January and December), with a peak in September. This indicates that the spawning period lasts for 10 months (February–November), while a



maximum number of individuals spawn in September, which is the pre- (northeast) monsoon period in Porto Novo.

In male *C. lida* (Fig. 12), immature (Stage-I) specimens occurred throughout the year, except July and September, with a peak in January. Specimens at Stage II (maturing) were observed throughout the year, with high percentages at all months, except August and

September. Stage-III (mature) males were available throughout the year, with a peak in September. This indicates that spawning occurs throughout the year, but a maximum number of males also seemed to spawn during September. Maximum occurrence of mature males in September corresponds with maximum occurrence of oozing females in the same period, and supports this view.



**Ova diameter** Ova diameter frequencies, from ovaries of Stage I–VI, are shown in Figure 13 for *C. arel* and *C. lida*. Since immature, transparent, and microscopic ova ( $\leq 0.11$  mm) outnumbered the maturing ova

during all stages of maturity, only ova  $> 0.11$  mm were taken into consideration, from Stage II onwards. Progressive maturation to spawning condition was evident from increasing ova diameters of the most advanced mode at each stage.

For *C. arel* (Fig. 13) in Stage I, maximum number of ova measured 0.01–0.04 mm; however, a few relatively larger ova (0.09–0.11 mm) were also recorded. In Stage II, a mode was discernible with a stock of ova (0.16–0.19 mm) separated from immature stock. In Stage III, the previous mode (at 0.16–0.19 mm) shifted to 0.24–0.26 mm. In Stage IV, a mode made by opaque ova was observed at 0.36–0.38 mm. In Stage V, two modes were found, one with a peak at 0.43–0.45 mm, and another at 0.50–0.53 mm. In Stage VI, the preceding two modes formed jointly a single mode, with fully mature, transparent, and large-sized ova of 0.54–0.56 mm.

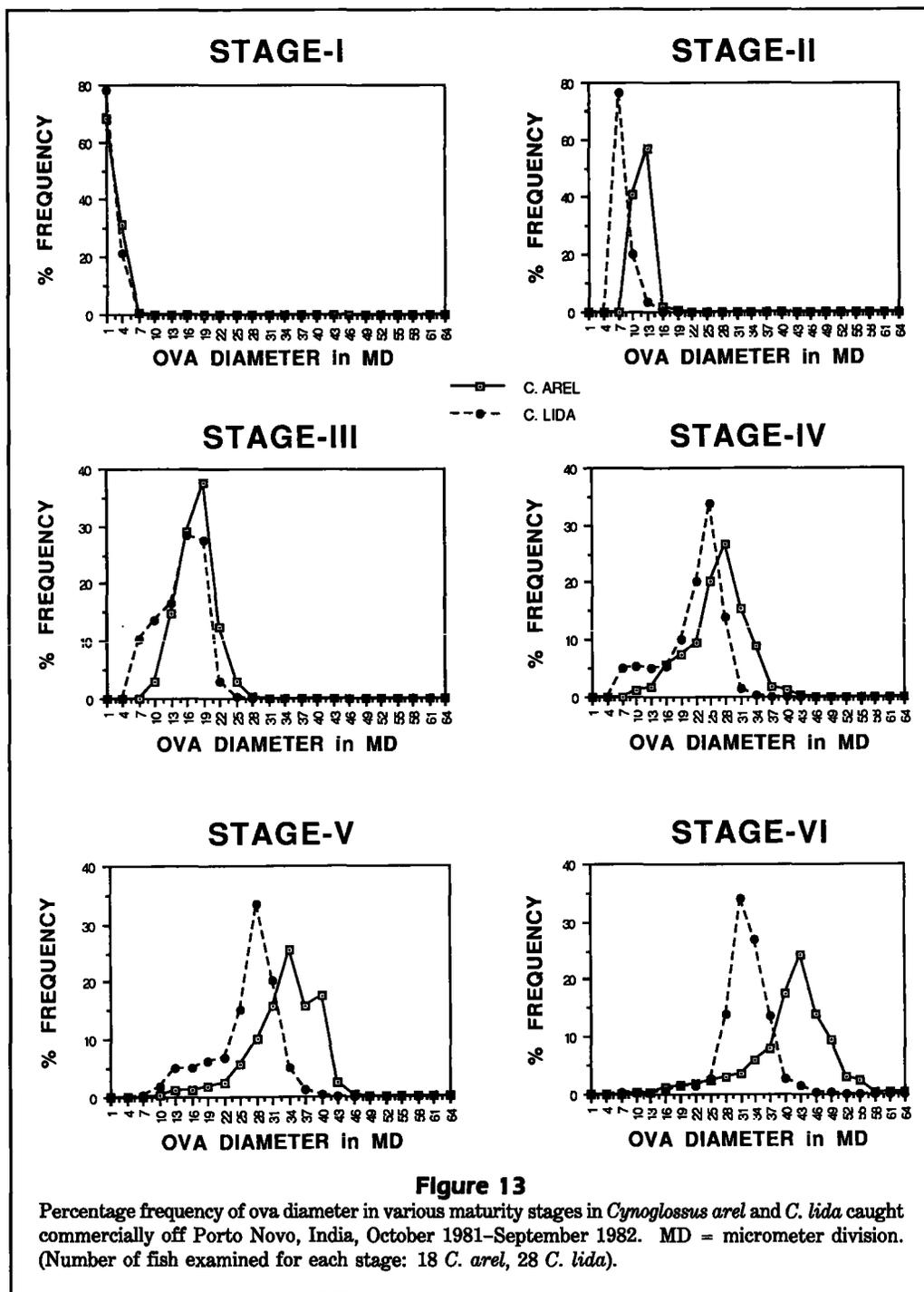
For *C. lida* (Fig. 13) in Stage I, immature ova measured 0.01–0.04 mm. In addition, a few relatively larger ova (0.09–0.11 mm) were also seen. In Stage II, a mode was discernible with a stock of ova at 0.09–0.11 mm, which was separated clearly from immature ova. In Stage III, the previous mode was shifted to 0.20–0.23 mm. In Stage IV, a mode of opaque ova was located at 0.31–0.34 mm. In Stage V, a mode of ripe ova was noted at 0.35–0.38 mm. In Stage VI, fully mature, transparent, and large-sized ova formed a mode at 0.39–0.41 mm.

Results indicate that individuals of *C. arel* and *C. lida* spawn only once during each season. Further, mature modes were wide-based (0.49–0.83 mm in *C. arel*, and 0.34–0.64 mm in *C. lida*); therefore, the spawning period of these species must be extended.

**Gonadosomatic Index** In male *C. arel* (Fig. 14), the highest GSI peak was in March, and the lowest GSI value was observed in January. In female *C. arel* (Fig. 14), the highest GSI peak was observed in November, and the lowest value was in January. In both sexes of *C. arel*, the peak values of GSI did not correspond with the observed spawning period in that year.

In male *C. lida* (Fig. 14), the highest GSI peak occurred in September, and the lowest value was in January, November, and December. In female *C. lida* (Fig. 14), the highest GSI peak was observed in May, while the lowest value was in December. Only in male *C. lida* did the high GSI peak coincide with the observed peak spawning period in September.

**Relative condition factor (Kn)** In male *C. arel* (Fig. 14), the highest Kn value peak was observed in February, and the lowest value was in October. In female *C. arel* (Fig. 14), the highest Kn peak was observed in January, and the lowest value was in November. Only

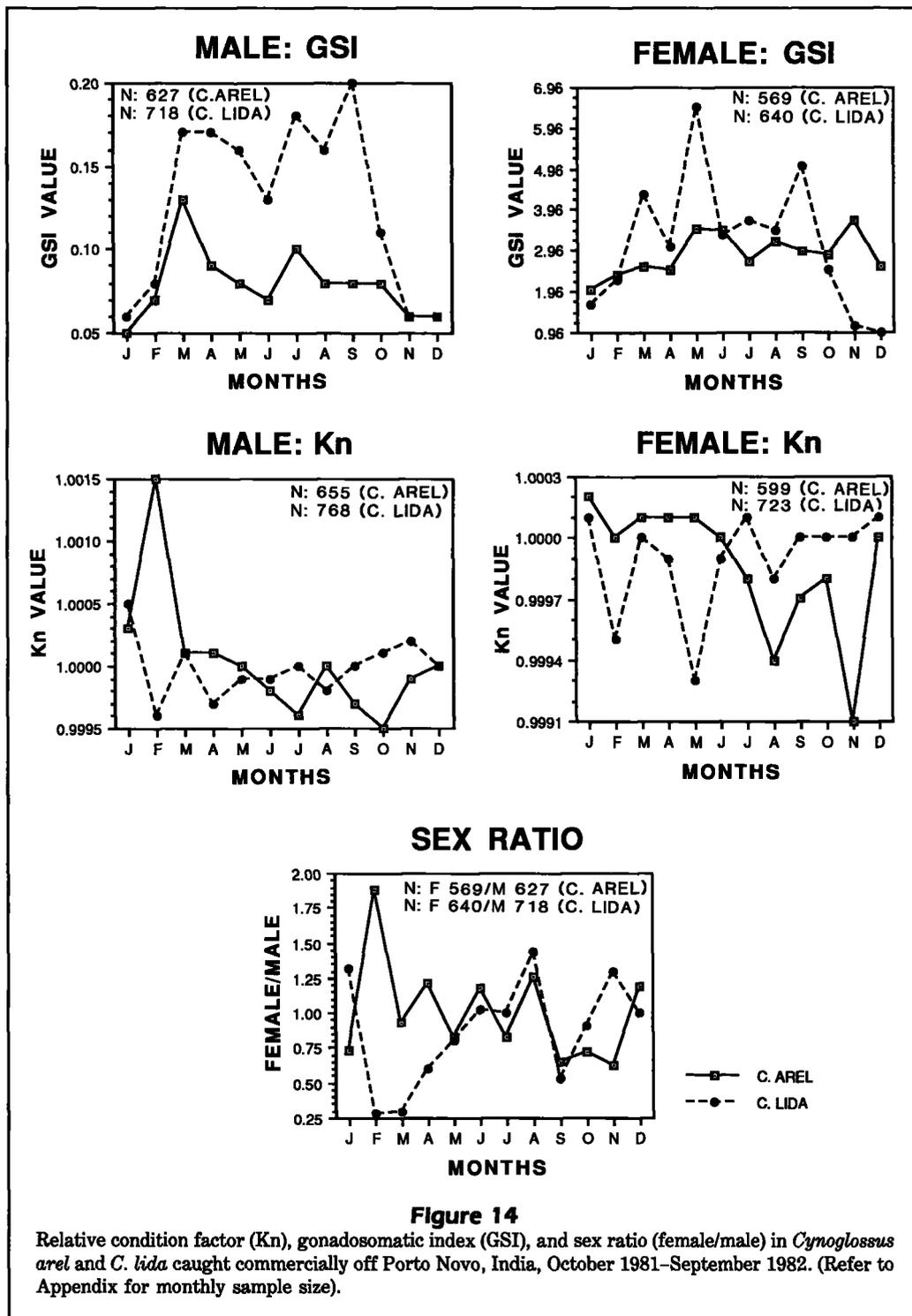


in female *C. arel* did a rise in Kn value correspond with a rise in gonadal activity, indicating the spawning period (in January).

In male *C. lida* (Fig. 14), the highest Kn peak was seen in January and the lowest value was in February. In females of *C. lida* (Fig. 14), the highest Kn peaks were seen in January, July, and December, and the lowest value in May. In both sexes of *C. lida*, a rise

in Kn value did not indicate the spawning period.

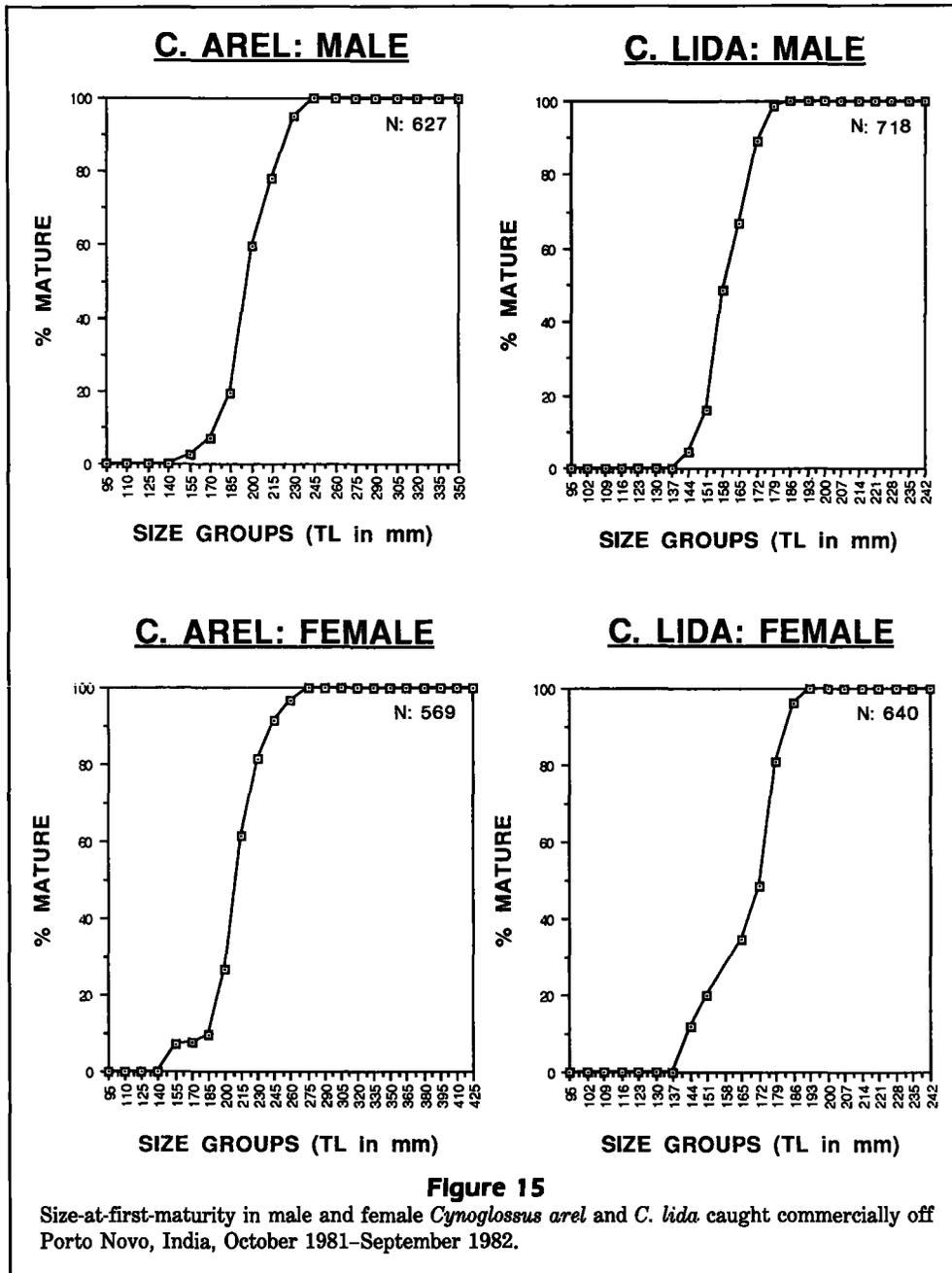
**Size-at-first-maturity** Both sexes of *C. arel* began to mature after the 140–154 mm size-group (Fig. 15). From the 155–169 mm size-group onwards, percentage occurrence of mature males and females increased steadily. Maturity reached 100% in the 245–259 mm size-group in males, and in the 275–289 mm size-group



in females. The calculated  $L_m$  for *C. arel* was 217 mm for males and 225 mm for females.

In *C. lida*, no specimen of either sex was mature until the 137–143 mm size-group, and the percentage occurrence of mature specimens increased gradually from

then on (Fig. 15). All male fish were mature at the 186–192 mm size-group, and females at the 193–199 mm size-group. In *C. lida*,  $L_m (=L_{50})$  was calculated as 167 mm for males and 179 mm for females. In both species, males mature at a smaller size than females.

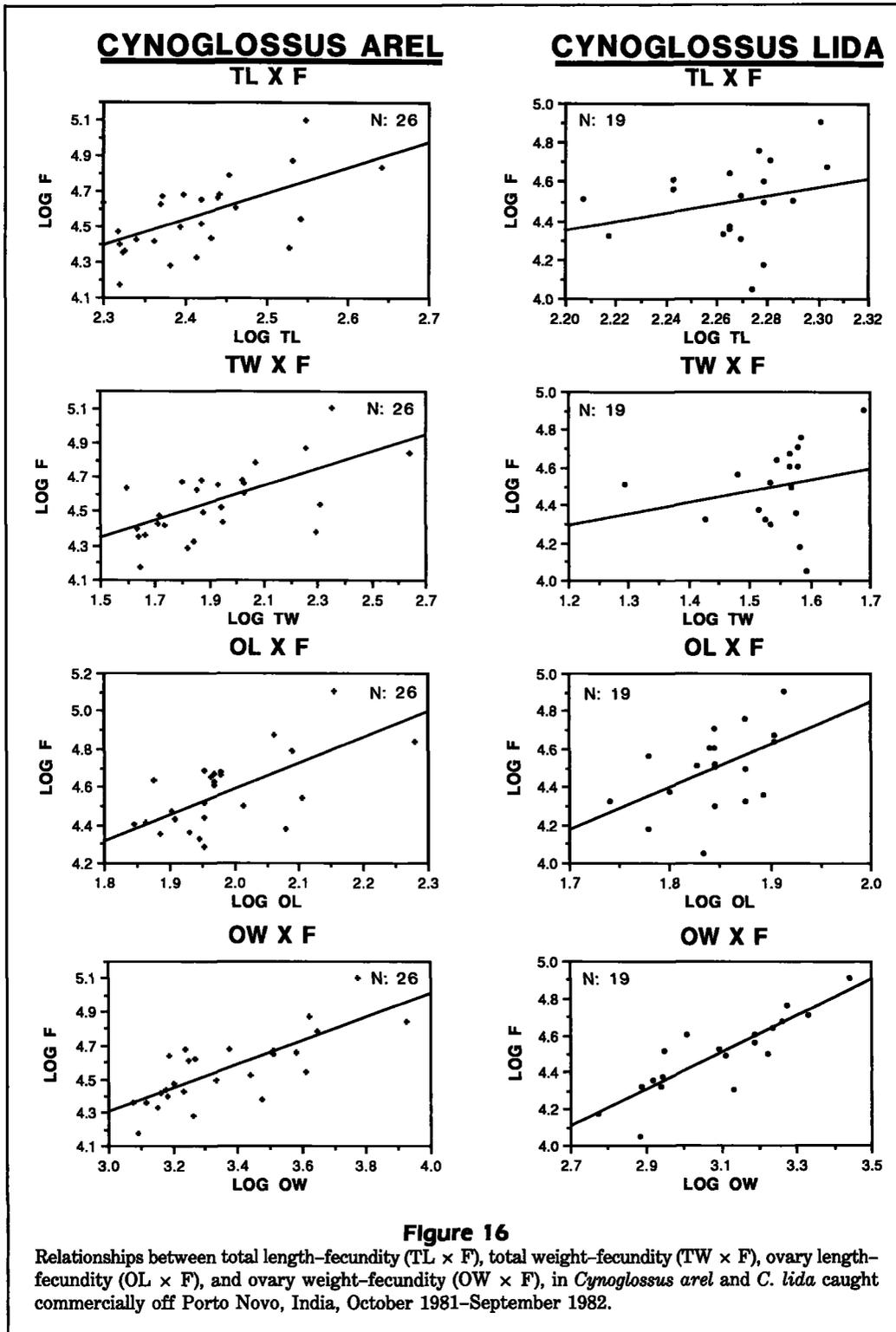


**Age-at-first-maturity** In their first year, males of *C. arel* grow to 180mm according to the Petersen method, and to 194mm according to the probability plot method and von Bertalanffy's equation (Rajaguru 1987). Female *C. arel* reached 201mm as per the probability plot method and von Bertalanffy's equation, and 210mm according to the Petersen method, at the end of their first year of life (Rajaguru 1987). Hence it appears that 50% of male and female *C. arel* attain first maturity at the beginning of their second year of life.

Male *C. lida*, at the end of their first year of life,

would grow to 151–154mm based on all three methods (Rajaguru 1987). Females of *C. lida* reach 153mm according to von Bertalanffy's equation and the probability plot method, and 156mm according to the Petersen method, at the end of the first year of their life (Rajaguru 1987). Therefore, 50% of male and female *C. lida* attain first sexual maturity during the second year of their life.

**Fecundity** Fecundity varied from 14,972 to 127,001 eggs/ovary in *C. arel*, and 11,267 to 81,004 eggs/ovary



in *C. lida*. Number of ova/g body weight was 124–1096 ( $\bar{x}$  464) in *C. arel*, and 287–1664 ( $\bar{x}$  988) in *C. lida*. Scatter diagrams of fecundity (F) against TL, TW, OL, and OW are shown in Figure 16.

Fecundity was found to increase with TL (Fig. 16). The calculated equation for F against TL is,  
*C. arel*  $\log F = 1.0629 + 1.4459 \log TL$   
*C. lida*  $\log F = -0.4923 + 2.2006 \log TL$ .

The correlation coefficient ( $r$ ) for this relationship in *C. arel* is 0.6043 ( $P < 0.001$ ) and is statistically significant; in *C. lida*, it is 0.2579 ( $P > 0.05$ ) and is not statistically significant.

Fecundity against TW showed a linear relationship (Fig. 16), and equations for the transformed data are,

$$C. \textit{arel} \quad \log F = 3.5907 + 0.4995 \log TW$$

$$C. \textit{lida} \quad \log F = 3.5536 + 0.6108 \log TW.$$

The correlation coefficient ( $r$ ) for this relationship in *C. arel* is 0.6345 and is highly significant ( $P < 0.001$ ); in *C. lida*, the correlation coefficient of 0.2302 ( $P > 0.05$ ) did not indicate a significant correlation between these two variables.

Ovary length showed a straight-line relationship with fecundity (Fig. 16). In logarithmic form, the relationships between  $F$  and  $OL$  can be expressed as follows;

$$C. \textit{arel} \quad \log F = 1.8472 + 1.3693 \log OL$$

$$C. \textit{lida} \quad \log F = 0.3206 + 2.2630 \log OL.$$

The correlation coefficient in *C. arel* is 0.6632 ( $P < 0.001$ ) and is statistically significant; in *C. lida*, it is 0.4990 ( $P < 0.05$ ), showing a high degree of correlation.

Fecundity plotted against  $OW$  showed a linear relationship (Fig. 16) and equations for these two variables are,

$$C. \textit{arel} \quad \log F = 2.1858 + 0.7050 \log OW$$

$$C. \textit{lida} \quad \log F = 1.3909 + 1.0038 \log OW.$$

The correlation coefficient in *C. arel* is 0.7729 ( $P <$

0.001), indicating a high degree of correlation between these two variables. In *C. lida*, the correlation coefficient of 0.8606 ( $P < 0.001$ ) is highly significant.

In the present study, the exponential value ( $b$ ) for total length–fecundity was higher than for total weight–fecundity. Similarly, the  $b$  value for ovary length–fecundity was higher than for ovary weight–fecundity.

**Sex ratio** The sex ratio was about 1:1 for both species (Table 18, Fig. 14). However, the ratio varied in monthly samples, and chi-square values showed a significant deviation from the expected 1:1 ratio for 3 months (February, September, and November) in *C. arel*, and during February–April, September, and November in *C. lida*. Since data were pooled for one year, the chi-square value conformed to the expected 1:1 ratio in *C. arel*; whereas in *C. lida*, it deviated significantly from the expected 1:1 ratio. The deviation may be due to multiple testing.

## Discussion

### Feeding ecology

*Cynoglossus arel* and *C. lida* feed predominantly on polychaetes and crustaceans, followed by other phyla such as molluscs, echinoderms, and coelenterates. These similarities in diets indicate common feeding strategies within the tonguefishes and soles (Seshappa and Bhimachar 1955, Kuthalingam 1957, de Groot 1971, Braber and de Groot 1973ab, Stickney 1976, Percy and Hancock 1978, Langton and Bowman 1981, Wakabara et al. 1982, Langton 1983, Honda 1984).

**Table 18**

Sex ratio of *Cynoglossus arel* and *C. lida* caught commercially off Porto Novo, India, October 1981–September 1982.  $F$  = Probability.

Months	<i>Cynoglossus arel</i>							<i>Cynoglossus lida</i>						
	$\sigma N$	$\varphi N$	$\sigma \%$	$\varphi \%$	$\sigma:\varphi$	$\chi^2$	$F$	$\sigma N$	$\varphi N$	$\sigma \%$	$\varphi \%$	$\sigma:\varphi$	$\chi^2$	$F$
Jan.	53	39	57.6	42.4	1.4:1.0	2.1304	>0.05	32	42	43.2	56.8	0.8:1.0	1.3514	>0.050
Feb.	24	45	34.8	65.2	0.5:1.0	6.3913	<0.05	59	16	78.7	21.3	3.7:1.0	24.6533	<0.001
Mar.	54	49	52.4	47.6	1.1:1.0	0.2427	>0.05	64	18	78.0	22.0	3.6:1.0	25.8049	<0.001
Apr.	46	55	45.5	54.5	0.8:1.0	0.8020	>0.05	84	51	62.2	37.8	1.7:1.0	8.0667	<0.010
May	56	45	55.4	44.6	1.2:1.0	1.1980	>0.05	38	31	55.1	44.9	1.2:1.0	0.7101	>0.050
June	35	40	46.7	53.3	0.9:1.0	0.3333	>0.05	56	59	48.7	51.3	0.9:1.0	0.0783	>0.050
July	69	56	55.2	44.8	1.2:1.0	1.3520	>0.05	25	25	50.0	50.0	1.0:1.0	0.0000	—
Aug.	44	54	44.9	55.1	0.8:1.0	1.0204	>0.05	43	62	41.0	59.0	0.7:1.0	3.4381	>0.050
Sep.	56	35	61.5	38.5	1.6:1.0	4.8462	<0.05	46	25	64.8	35.2	1.8:1.0	6.2113	<0.050
Oct.	75	54	58.1	41.9	1.4:1.0	3.4186	>0.05	83	76	52.2	47.8	1.1:1.0	0.3082	>0.050
Nov.	86	54	61.4	38.6	1.6:1.0	7.3143	<0.01	160	207	43.6	56.4	0.8:1.0	6.0191	<0.050
Dec.	29	34	46.0	54.0	0.9:1.0	0.3968	>0.05	28	28	50.0	50.0	1.0:1.0	0.0000	—
Total	627	560	52.8	47.2	1.1:1.0	3.7818	>0.05	718	640	52.9	47.1	1.1:1.0	4.4801	<0.050

Diet of fishes is related not only to their feeding behavior, but also to their digestive morphology and mouth structure (Stickney et al. 1974). In *C. arel* and *C. lida*, jaws are asymmetrical so that the mouth points to the bottom when opened, aiding feeding upon benthic prey. Flatfishes that feed on benthos usually have asymmetrical jaws (Pearcy and Hancock 1978). *Cynoglossus arel*, *C. lida*, and other tonguefishes are, in general, polychaete feeders. These fishes have small stomachs (not highly demarcated) and long intestines, and lack gillrakers and pyloric caecae.

Although there were similarities in food items, importance of prey species differed between adults and juveniles. Juveniles of *C. arel* and *C. lida*, probably owing to their very small mouths, fed predominantly on smaller prey such as amphipods and copepods, and ingested fewer types (only 10) of food items. Adults of both species, in contrast, had eaten 24 and 29 types, respectively, of relatively large-sized prey, primarily polychaetes, prawns, crustacean fragments, and fish remains. Mouth size severely limits the size of prey which can be ingested (Stickney 1976). According to Honda (1984), the extent of food demand and ability for food acquisition increase with growth and development of fish. Lande's (1976) findings on the dab *Limanda limanda* revealed that larger fish consumed large-sized prey compared with smaller fish. Pearcy and Hancock (1978) studied feeding habits of Dover sole *Microstomus pacificus*, rex sole *Glyptocephalus zachirus*, slender sole *Lyopsetta exilis*, and Pacific sanddab *Citharichthys sordidus* off Oregon, and concluded that the number and size of prey taxa generally increased with size in these flatfishes, due to the ability of larger fish to consume a larger range of prey sizes than smaller fish.

During the present investigation, fewer empty stomachs were noted in female than male (11.6% vs. 18.0%) *C. lida*. A similar trend was observed by Langton (1983) for yellow-tail flounder *Limanda ferruginea* off the northeastern United States. In female and male *C. arel*, the percentage occurrence of empty stomachs was similar (7.7% vs. 8.0%).

Sexual differences in food and feeding habits of flatfishes have not been reported. In this study, there was some indication of differences in prey between males and females. The primary food group (polychaetes) was the same in both sexes of *C. lida*; however, polychaetes were somewhat more important in females (IRI 65.9%) than males (IRI 53.4%). Moreover, the breadth of the diet was somewhat less in females which fed upon only 19 food types, in contrast to males in which 24 prey types were consumed.

The present analysis on feeding intensity reveals that in males of *C. arel*, the peak occurrence of empty stomachs had a positive correlation with peak spawn-

ing activity (in January). Spawning fish contained the least amounts of prey, or had empty stomachs. This result is consistent with the findings of Ramanathan and Natarajan (1980) on Indian halibut *Psettodes erumei* and flounder *Pseudorhombus arsius*, and with those of Langton (1983) on yellowtail flounder *Limanda ferruginea*. However, in female *C. arel* and both sexes of *C. lida*, the occurrence of empty stomachs had no obvious relationship with spawning activities. Seshappa and Bhimachar (1955) also reported that in Malabar sole *C. semifasciatus*, feeding intensity was not interrupted by increased reproductive activity.

Male and female *C. arel* showed an inverse relationship between gastrosomatic/hepatosomatic indices and breeding cycle, with the lowest values observed during peak spawning (in January). This indicates that gut/liver energy reserves may be used for gonadal recrudescence. Such a correlation was observed by Ramanathan (1977) for the Indian halibut *Psettodes erumei* and flounder *Pseudorhombus arsius*. Wingfield and Grimm (1977) found HI to be highest in the prespawning season and lowest in the postspawning period of the Irish Sea plaice *Pleuronectes platessa*. However, *C. lida* did not show a relationship between gastrosomatic/hepatosomatic indices and breeding cycle.

Although the primary diet of these two demersal flatfishes consisted of benthic prey such as polychaetes, prawns, echinoderms, and molluscs, it was surprising to find that pelagic amphipods ( $\leq 59.2\%$  IRI) and copepods ( $\leq 44.7\%$  IRI) were also relatively important in their diets, especially in juveniles. *Cynoglossus arel* and *C. lida* are demersal flatfishes that have never been caught in the pelagic waters off Porto Novo, either during day or night. These tonguefishes are not known to undergo vertical feeding migrations. Based on the present study, it is speculated that these tonguefishes ingested pelagic prey such as hyperiid amphipods and copepods when these prey organisms approached or contacted the bottom during vertical migrations through the water column. Hyperiid amphipods have been reported to undertake extensive vertical migrations (Bowman et al. 1982, Roe et al. 1984, Clark et al. 1989). Isaacs and Schwartzlose (1965) and Pereyra et al. (1969) have reported that in the eastern North Pacific Ocean, demersal fishes feed on pelagic prey, when such prey approach the bottom along the edge of the continental shelf.

Polychaetes, prawns, amphipods, copepods, crustaceans, and fishes were important prey for both *Cynoglossus arel* and *C. lida*. These tonguefishes shared 25 different food items as prey (out of 30 food types in *C. arel*, and out of 26 in *C. lida*). High overlap in diet may reflect abundant prey resources, reducing competition. Lande (1976) observed such a high prey

abundance for Norwegian flatfishes. However, during the present study, some individuals had full and gorged stomachs, filled only with either polychaetes or prawns. This might indicate either greater availability or patchy distribution of the major food items. Seshappa and Bhimachar (1955) reported for Malabar sole *Cynoglossus semifasciatus*, from the west coast of India, that during certain months the guts were gorged with only one prey, mostly polychaetes.

During the present investigation, most stomachs of *C. arel* and *C. lida* were found to contain considerable quantities of sediment (sand and mud). In some specimens, the entire stomach was filled with sediment. Algal filaments were also found in some stomachs. Sediment and algal filaments were probably ingested accidentally with bottom-living polychaetes and other infauna. Since demersal fishes browse near the sea bottom, some amount of sediment may frequently be in their gut. This has been reported for other flatfishes, such as Malabar sole *Cynoglossus semifasciatus* (Seshappa and Bhimachar 1955) and *C. lingua* (Kuthalingam 1957), and for other demersal fishes (Sedberry and Musick 1978). Stickney (1976) stated that the high percentage occurrence of sand in the stomachs of blackcheek tonguefish *Symphurus plagiusa* might be due to ingestion of a significant quantity of detrital material in its feeding activities. It is unknown if sediment ingestion in *C. arel* and *C. lida* is accidental or represents a deliberate feeding action. *In situ* or aquarium studies on feeding habits would be required to answer this question.

Nematodes, present in stomachs of several specimens of *C. arel* and *C. lida*, were not attached to the stomach wall but, rather, appeared to be free-living species.

### Age and growth

In the present study, distinct annual markings were not seen in scales, otoliths, opercular bones, and supraoccipital crests of *C. arel* and *C. lida*. Struhsaker and Uchiyama (1976) have stated that tropical and subtropical fishes are difficult to age, because they generally experience little seasonal and environmental changes and so do not develop annual rings clearly.

It was observed in *C. arel* and *C. lida* that after very rapid growth during the first year, there is a considerable reduction in the growth rate during the years when sexual maturity sets in; afterwards, the growth rate decreases slightly with age. This observation is consistent with the findings of Ford (1933) and Devold (1942).

Females of *C. arel* show faster growth, compared with males, and also live longer. According to Pitt (1966, 1967), since males mature earlier than females, it seems likely that energy is diverted at an earlier

age from growth to reproduction, so that the rate of growth in males is reduced at an earlier age than in females. Results of age and growth studies on yellow-tail flounder *Limanda ferruginea* from New England (Lux and Nichy 1969), *Limanda herzensteini* from Japan (Wada 1970a), Agulhas sole *Austroglossus pectoralis* from South Africa (Zoutendyk 1974a), and *Solea solea* from Spain (Ramos 1982) are also consistent with Pitt's view. In contrast to the above view, no significant difference was observed between the growth patterns in males and females of *C. lida*.

It is important to know at what age fishes are recruited to the fishery. The present study reveals that *C. arel* and *C. lida* reach commercial size during their 2d and 3d year. Botha et al. (1971) stated that Agulhas sole *Austroglossus pectoralis* off South Africa reached commercial size during their 3d–5th years, and at certain times their 2d–4th years. Lux and Nichy (1969) observed that yellowtail flounder *Limanda ferruginea* of the New England fishing grounds recruited to the commercial fishery during their 3d and 4th years. According to Seshappa and Bhimachar (1955), the bulk of commercial catches of Malabar sole *Cynoglossus semifasciatus* consisted of 2d-year individuals.

*Cynoglossus arel* and *C. lida* have a life-span of a little over 3 years in the southeast coast of India. The longevity for *C. lida* from the west coast of India has also been reported to be 3–4 years (Seshappa 1978). Longevity in most tropical fish species is relatively shorter and seldom exceeds 2–3 years (Qasim 1973b). However, temperate flatfishes were reported to have a longevity of 6–30 years (Devold 1942, Arora 1951, Pitt 1967, Lux and Nichy 1969, Lux 1970, Wada 1970a, Zoutendyk 1974a, Smith and Daiber 1977).

### Length-weight relationships

During the present analyses, *C. arel* showed differences in characteristic length-weight slopes for males and females. Similar observations were made by Ketchen and Forrester (1966) and Powles (1967), while analyzing the length-weight relationships of Petrale sole *Eopsetta jordani* and American plaice *Hippoglossoides platessoides*, respectively. However, *C. lida* showed no significant differences in characteristic length-weight slopes for males and females. Zoutendyk (1974b) on Agulhas sole *Austroglossus pectoralis*, and Smith and Daiber (1977) on summer flounder *Paralichthys dentatus*, did not report significant differences in length-weight characteristics of males and females.

*Cynoglossus arel* and *C. lida* showed significant regression coefficients (b-values), which differed significantly from the hypothetical B value (=3). Webb (1972) made similar observations for yellow-bellied flounder *Rhombosolea leporina*.

Significant deviation from the 'cube law' was observed in mature females of *C. lida* due to gonad development. Similar findings were observed by Dawson (1962) in hogchokers *Trinectes maculatus*, and by Lux (1969) in yellowtail flounder *Limanda ferruginea*.

In male and female *C. arel*, and male, female, and juvenile *C. lida*, the exponent values are  $>3$ , indicating that the weight increase is more in relation to length. But the exponent value for juveniles of *C. arel* is  $<3$ , indicating that an increase in weight is less compared with length.

During the present investigation, specimens  $<83$  mmTL in *C. arel* and  $<81$  mmTL in *C. lida* were not available from the continental shelf off Porto Novo. Arora (1951) reported such an absence of juveniles in the commercial catches for California sand dab *Citharichthys sordidus*. Non-availability of juveniles in commercial catches might be due to the gears operated or due to their occurrence in deeper waters, since spawning of cynoglossines in inshore waters has not been reported (Seshappa and Bhimachar 1955).

### Reproductive biology

Spawning periods of *C. arel* and *C. lida* were prolonged, lasting for 10 months. The present study agrees with Qasim's (1973a) view that in Indian waters many fish species may be prolonged breeders. Seshappa and Bhimachar (1955) reported that the spawning season in the Malabar sole *Cynoglossus semifasciatus* off the west coast of India was prolonged (8 months).

In *C. arel* and *C. lida*, ova in different maturity stages taken from anterior, middle, and posterior regions of both lobes of ovaries showed no variation in their mean diameter. It is therefore concluded that the development of ovarian eggs proceeds uniformly throughout the ovary. Such a distribution of ova has been reported for Indian halibut *Psettodes erumei* and flounder *Pseudorhombus arsius* (Ramanathan and Natarajan 1979).

Male *C. arel* and *C. lida* attained maturity earlier than females. Pitt (1966) observed that males of American plaice *Hippoglossoides platessoides* were obviously smaller than females at first maturity. Results obtained by Lux and Nichy (1969) for yellowtail flounder *Limanda ferruginea* (New England), by Wada (1970b) for *Limanda Herzensteini* (Japan), by Zoutendyk (1974a) for Agulhas sole *Austroglossus pectoralis* (South Africa), and by Ramos (1982) for *Solea solea* (Spain) were similar to the present findings.

The GSI is used widely as an index of gonadal activity and as an index for spawning preparedness. In male and female *C. arel* and in female *C. lida*, GSI did not accurately reflect gonadal activity; the relation of gonadal weight to body weight did not change with

stage of gonadal development. de Vlaming et al. (1982) stated that the GSI is widely and consistently used for gonadal size and activity without verification of its validity. According to de Vlaming et al. (1982), the GSI is not always the best way of expressing gonadal activity, and so this index should not be applied without validation. Chrzan (1951) concluded that the ratio of gonad weight to body weight, which normally characterizes sexual maturity, could not be determined exactly. According to Delahunty and de Vlaming (1980), the exponential relationship between ovarian weight and body weight did not change with the phase of oocyte development. However, in male *C. lida*, higher values of GSI indicated the occurrence of fully-mature specimens during this period, and a sudden fall in GSI value after September appeared to be due to spawning. Such a relationship between GSI and gonadal activity was reported for Indian halibut *Psettodes erumei* and flounder *Pseudorhombus arsius* (Ramanathan and Natarajan 1979).

In male *C. arel* and male and female *C. lida*, a rise in Kn value did not correspond with a rise in gonadal activity. Webb (1973) observed no significant variation in body condition, with onset of spawning, in sand flounder *Rhombosolea plebeia* and yellow-bellied flounder *R. leporina* off New Zealand. However, in female *C. arel*, a rise in Kn value corresponded with a rise in gonadal activity, and thus showed a positive correlation.

A linear relationship between fecundity and other variables (total length, total weight, ovary length, and ovary weight) was observed in *C. arel* and *C. lida*. The result agrees with those of Hoda (1976). The correlation coefficient between fecundity and total length, total weight, ovary length, and ovary weight showed a high positive degree of correlation in *C. arel*. In *C. lida*, the correlation coefficient between fecundity and ovary length and ovary weight showed a high positive degree of correlation; whereas the correlation coefficient between fecundity and total length and total weight did not show significant correlations. Hence in *C. lida*, fecundity was dependent only on ovary length and ovary weight.

In *C. arel* and *C. lida*, fecundity was better correlated with total length and ovary length than with total weight and ovary weight. According to Colman (1973), in sand flounder *Rhombosolea plebeia* and yellow-bellied flounder *R. leporina* off New Zealand, fecundity increased at a rate greater than the cube of length, and more than proportionately to weight; fecundity was probably slightly less proportional to ovary weight. Colman (1973) suggested that this might be due to large ovaries containing either great quantities of ovarian fluid or connective tissue or a high proportion of nondeveloping eggs.

In *C. arel* and *C. lida*, age of fish had no effect on the number of eggs. Among fish of the same length, older ones did not contain more eggs than younger ones. This result is consistent with the findings of Simpson (1951) and Bagenal (1957).

More fecund *C. lida* (relative fecundity 287–1664,  $\bar{x}$  988) laid smaller eggs ( $\leq 0.6250$  mm d.m.), while less fecund *C. arel* (relative fecundity 124–1096,  $\bar{x}$  464) laid larger eggs ( $\leq 0.8125$  mm d.m.). Dahl (1918) and Svårdson (1949) also found that more fecund species lay smaller eggs.

In *C. arel* and *C. lida*, males outnumbered females and were relatively smaller in size than females. The present finding is inconsistent with Qasim's (1966) view that the sex which outnumbers the other attains a much bigger size.

Chi-square values showed a significant deviation from the expected 1:1 ratio for 3 months in *C. arel* and for 5 months in *C. lida*. Such a deviation could be due to a partial segregation of mature forms through habitat preference (Reynolds 1974), due to migration (Collignon 1960) or behavioral differences between sexes (Polonsky and Tormosova 1969), thus rendering one sex to be more easily caught than another.

During the present investigation, spent individuals of *C. arel* and *C. lida* were not found throughout the study period, since spawning of tonguefishes appears to take place mainly in deeper waters, as observed by Seshappa and Bhimachar (1955) for Malabar sole *Cynoglossus semifasciatus*. This is a gap in the reproductive biology of these tonguefishes. Deep-sea fishing is needed to confirm this type of spawning behavior by the tonguefishes.

For *C. arel*, the spawning peak was in January which is the post-(northeast) monsoon period along the south-east coast of India. Monsoonal floods end by this time, and food resources (like copepods and amphipods, which are essential food items of juveniles) are abundant; this season would appear to be a favorable time for spawning. The spawning peak of *C. lida* was in September, which is the pre-(northeast) monsoon period along the southeast coast of India; this period coincides with the most active southwest monsoon period along the west coast of India. Most of the rivers originating in the west receive floodwaters through the southwest monsoon and empty them into the Bay of Bengal, which thus gets rich primary food resources at this time. This period would also appear to be a favorable time for spawning, because of food abundance.

Thus *C. arel* and *C. lida*, though co-occurring sympatrically in the continental shelf waters off Porto Novo, share available food resources and appear to avoid competition for food and space for their juveniles by exhibiting spawning peaks during different periods (pre-/post-northeast monsoon).

## Acknowledgments

I am indebted to Dr. Bruce B. Collette, Systematics Laboratory, for his many helpful suggestions in the modification of this manuscript for publication, and for providing the facilities of the Systematics Laboratory. My sincere thanks to Dr. Thomas Munroe for critically reviewing part (food and feeding) of the manuscript. Comments made by the editor, and two anonymous reviewers helped in modifying this manuscript. Special thanks go to Ms. Ruth E. Gibbons, for her suggestions regarding computer graphics. Grateful acknowledgement is extended to the University Grants Commission, New Delhi, to Dr. R. Natarajan, and to the authorities of Annamalai University, India, for offering financial support and necessary facilities to carry out this study as a part of my Ph.D. program. I thank Dr. K. Sriraman, Tamil Nadu Fisheries, Porto Novo, for his help in the statistics. My sister, Miss G. Shantha, helped me in processing the data. Computer help extended by Mr. H.A. Kurt Luginbyhl, Dr. Jeffrey Williams, Mr. Tom Orrell, and Mr. Jeffrey Howe is greatly appreciated.

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### Appendix

Monthly sample sizes (*n*) for various studies on biology of *Cynoglossus arel* and *C. lida* caught commercially off Porto Novo, India, October 1981–September 1982. GI = gastrosomatic index; HI = hepatosomatic index; GSI = gonadosomatic index; L-W = length-weight relationships; Kn = relative condition factor.

Months	GI/HI/GSI/Sex ratio				L-W/Kn				Age and growth			
	<i>C. arel</i>		<i>C. lida</i>		<i>C. arel</i>		<i>C. lida</i>		<i>C. arel</i>		<i>C. lida</i>	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
January	53	39	32	42	52	49	24	31	54	39	34	45
February	24	45	59	16	34	52	48	45	24	44	58	16
March	54	49	64	18	51	47	85	38	54	51	64	18
April	46	55	84	51	46	58	86	54	48	55	84	51
May	56	54	38	31	57	52	62	43	56	54	39	32
June	35	40	56	59	44	41	54	54	35	40	56	59
July	69	56	25	25	70	55	37	44	69	56	25	26
August	44	54	43	62	54	66	45	64	45	54	43	62
September	56	35	46	25	59	39	62	37	57	35	50	26
October	75	54	83	76	81	57	83	80	76	55	83	77
November	86	54	160	207	70	45	135	168	87	54	160	207
December	29	34	28	28	37	38	47	65	29	37	28	31
Total	627	569	718	640	655	599	768	723	634	569	724	650